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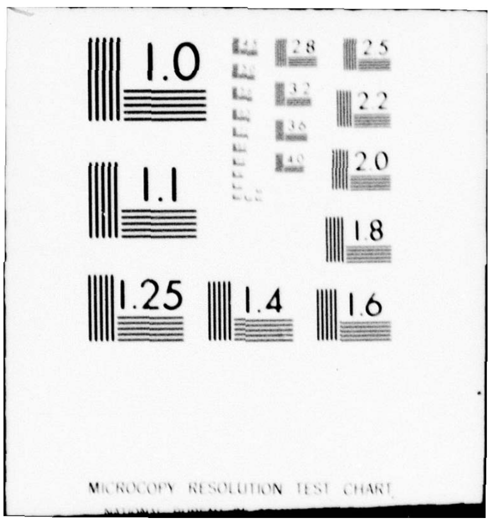
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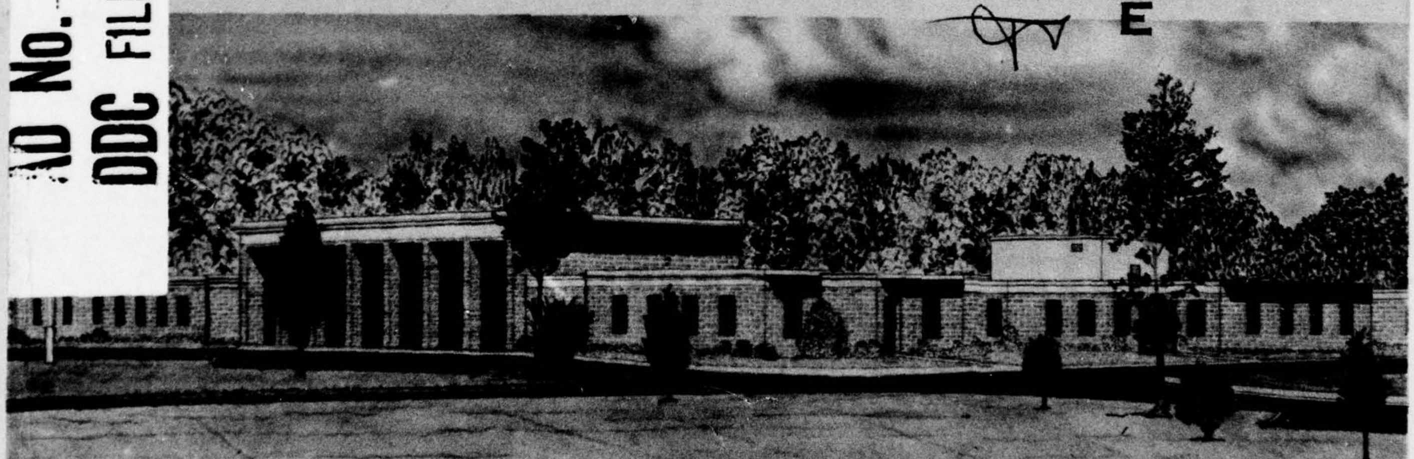

Prepared for U. S. Army Materiel Development and Readiness Command, DRCDE-E
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This bibliography on grouting contains abstracts of various engineering and scientific publications on both portland cement and chemical grouts. The technical data cover subjects such as: dams, bridges, buildings, machinery foundations, tunnels - sewers - shafts, silos, roadbeds, pavements, soils, rock bolts, and miscellaneous structures.

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PREFACE

This bibliography was prepared in the Library Branch, Technical Information Center, for the Concrete Technology Information Analysis Center (CTIAC). Members of the Library staff who contributed to its compilation were Mr. Ralph Peterson, Mr. Jerry Griffith, and Mrs. Esther Dunlap, under the direction of Miss Marie Spivey, Chief, Library Branch. Mr. Alan G. Skelton is Chief, Technical Information Center. The staff of the Concrete Laboratory, U. S. Army Engineer Waterways Experiment Station, provided technical guidance for the preparation of the bibliography under the general supervision of Messrs. B. Mather, Chief of the Concrete Laboratory and Director, Concrete Technology Information Analysis Center (CTIAC); J. M. Scanlon, Chief of the Engineering Mechanics Division; R. A. Bendinelli, Chief of the Grouting Branch; and Mrs. Katharine Mather, Assistant Director, CTIAC. This is CTIAC Report No. 13.

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The Commanders and Directors of WES during the preparation and publication of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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BIBLIOGRAPHY ON GROUTING

I. - DAMS

(Letters in the right-hand margin indicate the type of grouting covered by the reference as follows: P, portland cement; C, chemical; M, miscellaneous or multiple.)

BERGEFOSSEN--A SWEDISH POWER PLANT BUILT ON NONRESISTANT ROCK P

Aastrup, A.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, p.473-489.
This report gives an account of the conditions relating to the existence of Alno dikes at the dam site and of measures taken to prevent damage to the dams and the power station. Sealing operations were mainly carried out by means of cement grouting forming two grout curtains. A combination of cement grouting and lime water injections was chosen for sealing the bedrock along the major part of the dams. This treatment was however, not applied in the rock above the grouting tunnel under the southern earth dam, where the lime water process was replaced by asphalt grouting. The reasons for this were that only low pressure cement grouting would be allowed here because of the risk of piping in the partly completed earth dam and, consequently, that the consumption of lime water might become excessive. At places where particularly poor rock was encountered, additional concreting and grouting were effected in order to increase the bearing capacity of completely or partly disintegrated dikes, thus eliminating the risk of settlements.

FIELD TESTS FOR GROUTING NILE ALLUVIALS UNDER THE ASWAN HIGH DAM C, M

Abou Wafa, T.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, p.191-214.
Seepage under this high rock fill dam founded on permeable sand will be controlled by upstream blanket and grout curtain to bedrock. Grout tests and field pumping tests indicate the effect of using grouts consisting of a local clay and a deflocculated bentonite or a mixture of silicate and aluminate.

THE GREAT GROUT CURTAIN UNDER THE HIGH ASWAN DAM C, P

Abou Wafa, T., and Hanna Labib, A.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1., p.275-302.

This grout curtain will be the largest and deepest in the world. The paper furnishes information on the design and construction of the grout curtain. Cement-clay grouts were used for injection in coarse alluvials; bentonite silicate grouts for fine sands in the first application followed by pure silicate grout for repeated grouting. Pure clay grouts were used for repeated grouting after the cement clay.

NEW TECHNIQUES APPLIED TO THE DESIGN AND CONSTRUCTION OF THE ASWAN HIGH DAM (EGYPT)

Abou Wafa, T., and Hanna Labib, A.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.1, p.749-768.
Development aspects are given for all aspects of design and construction works of the Aswan High Dam. In the sediments beneath the clay core, grouting was applied to form an impermeable cutoff, the depth of which is far greater than the height of the dam.

FOUNDATION GROUTING AT THE HACKREN DAM P

Abrahmsen, R., and Edlund, L.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.353-66.
The foundation was grouted with cement to consolidate existing weak zones and reduce leakage through the rock to diminish the risk of washing out cracks and joints filled with earthy material. An account is given of measurement results of seepage water through the foundation rock and hydrostatic pressure in the rock under the core of the dam. The relation between seismic refraction measurements and the extent of grouting, as illustrated by the quantity of cement used, is also discussed.

MEASURES TAKEN TO STRENGTHEN THE OLD ASSWAN DAM P

Abu-el Dehab, A.H.M.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.3, p.591-608.
The masonry was grouted with cement and Kieselguhr so as to restore its mortar and prevent further deterioration due to the action of the Nile water. An impervious vertical grout curtain close to the U.S. face of the dam was constructed.

FOUNDATION AND ABUTMENT TREATMENT FOR ROCKFILL DAMS M

Acker, R.C., and Jones, J.C.

American Society of Civil Engineers, Journal of the Soil Mechanics and

Foundations Division, vol.98, SM10, p.995-1015, October 1972, Paper 9303.
Each high embankment dam presents unique foundation problems for the engineers involved in designing and building the structure. The practice of Harza Engineering Company concerning the foundation treatment of high rockfill dams on rock foundations is reviewed. Specific details of foundation treatment are described for four high rockfill dams designed by Harza and for which Harza supervised the construction. Blanket, consolidation and curtain grouting were used beneath the impervious core at each of the four dams under review. Cement grout mixes were normally used except for special situations requiring chemical grout or other special materials. Grouting pressures are set as a maximum permissable grouting pressure for each segment and depth zone of the curtain. The maximum permissible pressures are established on the basis of experience and geologic evaluation of individual site subsurface conditions. Test grouting programs often are used where believed to be warranted in addition to surface and subsurface geologic exploration, although no test grouting was done for these dams. An often used criterion, particularly at damsites where rock discontinuities are flat lying is that formational grouting pressures not exceed the load of the overlying rock. The utmost importance is attached to having experienced jobsite grouting supervision. The judgment of the man in the field in adjusting and tailoring grouting techniques to the conditions encountered in each grout hole is where the success and safety of the grouting program ultimately lies.

GROUTING, DRAINAGE, AND MEASUREMENTS OF DEFORMATIONS ON THE CONCRETE DAM RESTORED AFTER DESTRUCTION

Adamovich, A.N.

International Congress on Large Dams, 6th, New York, 1958, Transactions, vol.2, Question no.21, p.1273-1302.
The main type of reconstruction work on the structure of the power plant used was the application of the method of grouting on a large scale, as well as for the strengthening of the concrete masonry as for the thickening of the curtain with the aim of reducing the uplift and of increasing the stability of the dam.

USE OF ADDITIONS TO IMPROVE THE PROPERTIES OF MORTARS APPLIED FOR SOIL GROUTING IN DAM FOUNDATIONS M

Adamovich, A.N.

International Congress on Large Dams, 6th, New York, 1958, Transactions, vol.4, p.487-508.
Considers the conditions and methods of introducing the additives into the mixtures used for grouting the soils in dam foundations. The experimental data enabled proving the desirability of using widely varying quantities of clay additives which results in improvement of such important

technological properties of mortars as non-disintegration, homogeneity, reduction or complete elimination of water separation. Injection of finely dispersed plastic mixtures enables ensuring required tightness of curtains in present-day cementing operations with considerably greater distances between the holes than before. Use of clay additives in injection mixtures results in considerable savings of cement while retaining required tightness of the curtains.

FOUNDATION PROBLEMS AT WARRAGAMBA DAM M

Aiken, D.G.

International Congress on Large Dams, 8th, Edinburgh, 1964, Transactions, vol.1, p.1109-1131.

Discusses foundation problems encountered during construction of a dam on the Warragamba River--rock movements during excavation, presence of a fault under one abutment, and open joints and bedding planes causing interconnections between grout holes over wide areas.

PERMEABILITY AND PECULIARITIES OF GROUTING IN TUFFACIOUS FOUNDATION ROCKS OF THE ARAKS HYDROELECTRIC DEVELOPMENT P

Akhmedov, R.A., and Gadzhiev, A.B.

Hydrotechnical Construction, no.10, p.905-07, October 1971. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.10, p.7-8, October 1971.)

A grout curtain was stipulated and constructed for seeking and sealing relatively large joints, i.e., possible seats of intense percolation, some of which were probably not revealed by the subsurface surveys owing to the great distance between holes and the presence of steep joints. In addition, the grout curtain served to increase the strength of the foundation, especially where joints were filled with loam. Thus, the grout curtain had a control character, especially beyond the limits of the fault zone. According to the plan, the depth of the grout curtain was thirty meters. The curtain was single-row, except in some places along the front of the concrete structures and in the river channel, where it was two-row. The specific absorption in the control holes located between the injection holes was taken as the criterion of the quality of grouting. The usual grouting procedure was used. To determine the allowable injection pressures, some zones were hydraulically tested with a gradual increase of injection pressure. Testing of the control holes showed that the quality of the curtain meets the requirements of the plan.

SOME SPANISH DAM FOUNDATIONS ON ERODIBLE AND PERVIOUS FORMATIONS P

Alonso Franco, M. and Gomez Laa, G.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.123-135.

This paper deals with four examples of dams already completed in Spain, or under construction, founded on erodible and pervious soil. In the case of the Prada Dam, the problem consists in a sub-glacial riverbed which had to be consolidated and sealed. This was achieved by substituting the fines by a cement grout which formed a sort of concrete with the larger elements of the layer.

FOUNDATION TREATMENT OF GULUC DAM FOUNDED ON PERVIOUS RIVER ALLUVIUM M

Anik, F.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.609-618.
A clay grout was injected into alluvium in addition to a cutoff wall in the alluvium.

LES TRAVAUX D'ETANCHEMENT DES TERRAINS AU BARRAGE DE FOUM-EL-GHERZA P

Aris, R.

International Congress on Large Dams, 5th, Paris, 1955, Transactions, vol.1, p.463-491.
Extensive cement grouting operation undertaken for high arch dam in Algeria which was constructed in canyons hollowed out in very fissured limestone resting on a compact marl base. Many piezometers and weirs were employed in an elaborate observation system to follow the development of the flow pattern in the limestones.

PUEBLO DAM - A BUREAU OF RECLAMATION FIRST

Arthur, H.G.

Civil Engineering, vol.45, no.7, p.70-73, July 1975.
Discusses grouting during construction of Pueblo Dam in Colorado.

ASPHALT CUTOFF WALL AT CLAYTOR DAM M

Asphalt Institute Quarterly, vol.3, no.2, p.10-11, April 1951.
In completion of Claytor Hydroelectric Project, New River, Virginia, stoppage of underflow through north abutment of dam became necessary. This was accomplished by means of an asphalt cutoff wall. Article contains detailed description of underground formations, analysis of problem, method of attack of the problem, etc.

ASPHALT SEALS CONCRETE CUT-OFF IN ROCK FILL DAM M

Engineering News-Record, vol.94, p.532, March 26, 1925.
Junction of concrete slab on upstream face with cut-off wall was sealed with asphalt.

ASWAN HIGH DAM IS AT 80% MARK P

Engineering News-Record, vol.178, no.7, p.16, 16 February 1967.
Grout crews working from two lower galleries grouting a cutoff wall. The cutoff wall will extend more than 450 ft below the bottom of the dam and require 800,000 yards of grout. The 365-ft-high, 55-million-cubic-yard embankment is founded on pervious material and the grout cutoff will tie the dam's clay core into a sandstone formation.

AT WANAPUM DAM, CEMENT-BENTONITE-SILT COMBINATION GROUT USED UNDER LEFT BANK M

Pacific Builder and Engineer, vol.67, p.90-91, May 1961.
Drilling and grouting of a 564-foot-long cut-off wall under the left embankment at Wanapum Dam is the first use of these methods in the industry on this scale. It is the area between the concrete and bedrock--a layer ranging as deep as 145 feet below the surface--that must be plugged with grout. Bentonite is being used extensively on this job, both to keep holes open in drilling and mixed with cement for final grouting. The main grout mixture contains a mixture of fine silt and cement as a practical answer to the porous nature of material in this area. A considerable grouting program was necessary to prevent percolation under the embankment between the concrete and bedrock. Some grouting had been planned but depths as great as 145 feet on the east side were not expected. The grout holes are drilled two feet into the bedrock to make a complete seal.

AUSTRIANS GROUT AND WEDGE DAM IN PLACE M

Engineering News-Record, vol.178, no.3, p.30-31, 19 January 1967.
Austrian engineers are building a 3.5-million-cubic-yard rockfill dam at Durlassboden. To prevent seepage under the dam's alluvial foundation material, the engineers designed a grout curtain that extends across the valley under the entire length of the dam to a maximum depth of 230 feet, into densely packed and naturally impervious clayey material. Grout holes were drilled vertically on an 8 x 10-foot grid covering a band about 56 feet wide across the entire valley. Depths range from fifty feet along the sides of the band to 230 feet along the middle. The deep center rows penetrate about sixteen feet into the impervious material below the alluvium. The contractor used three types of grout, starting with a suspension heavy on cement and low on clay, followed by a mixture of cement-clay and

bentonite, and finally by an algonite gel suspension (a gel with silicate and phosphate additives). Grout was injected under pressure ranging from 355 to 425 psi, through some 65,600 feet of grout holes. An 8-foot-high, five-foot-wide concrete control tunnel runs the length of the dam under the core zone. The center row of grout holes is accessible from the tunnel for future grouting when it becomes necessary.

AVOID OVERCONFIDENCE IN THE GROUTING OF DAM FOUNDATIONS (LETTER)

Engineering News-Record, p.1017, June 28, 1928.
Limitations and one failure cited.

THE BACKWATER RESERVOIR WORKS OF THE EAST OF SCOTLAND WATER BOARD — C, P, M

Water and Water Engineering, vol.73, no.885, p.449-457, November 1969.
Three types of grout were used in the construction of the Backwater Reservoir: silicate, clay cement, and deflocculated bentonite. 550,000 cu ft of grout were injected into the ground.

A REVIEW OF BRITISH RESERVOIRS — P

Banks, J.A.

The Engineer, vol.220, p.789-790, November 12, 1965.
Backwater Dam (illustration). Dam on fringe of fault. A curtain is being formed by alluvial grouting.

THE CEMENTATION OF STRATA BELOW RESERVOIR EMBANKMENTS

Barnes, A.A.

Institution of Water Engineers, Transactions, vol.32, p.42, 1927.

BUREAU OF RECLAMATION EXPERIENCE IN STABILIZING EMBANKMENT OF FONTENELLE EARTH DAM — P

Bellport, B.P.

International Congress on Large Dams, 9th, Istanbul, September 4-8, 1967, Transactions, vol.1, p.67-79.
On September 3, 1965, the safety of Fontenelle in Wyoming was threatened when a substantial leak developed. This paper examines the foundation conditions, the design, and construction practices at the

dam to determine why this leak developed in spite of the precautions taken in the original design and construction. The paper discusses the modifications needed in investigations, design and construction practices to prevent a recurrence at this dam and other similar sites. The repairs, which consist of extensive and thorough grouting of the foundation and restoration of the embankment damaged by the sudden flows, are also discussed.

FOUNDATION TREATMENT FOR BENITO JUAREZ DAM P

Benassini, A.

American Concrete Institute Journal, vol.59, no.10, p.1479-1488, October 1962.

Grouting with portland cement to provide an impervious curtain and a well-compacted watertight blanket has, in many cases, corrected the existing foundation conditions and prevented seepage both at the dam footings and through the abutments. This paper discusses problems encountered in the construction of the Benito Juarez Dam in Mexico. The difficult problem of cavernous rock was solved using special techniques. A comparison with other dams is also included. A core trench was excavated along the axis of the dam to intercept the alluvial deposits and the decomposed or cavernous limestone. Confining curtains were provided along both edges of the core footing. These curtains prevented the grout from flowing outside the core footing area where it would have been wasted. For sealing of cracks and fissures and for cavity fillings in the main curtain grouting, borings were made with 1 1/2 inch diamond bits and carried to the final depth by successive stages.

INSTRUMENTATION IN ROCK GROUTING FOR PORTAGE MOUNTAIN DAM P

Benko, K.F.

Water Power, vol.18, p.407-15, October 1966.

Automatic grout flow pressure and foundation displacement recording instruments were developed for the foundation rock grouting at Portage Mountain Dam in British Columbia, Canada. Rock under the central core of the dam was gunited and blanket grouted prior to constructing the grout curtain. The curtain consists of three to five lines of grout holes, spaced fifteen feet apart. The closure method of grouting is followed both across and along the lines of holes, the outside lines of holes being grouted first, followed by the intermediate and centerline holes. Each grout recorder system consists of a main recording cabinet located at the grouting plant or inside the central grouting station and a pressure transmitter cabinet installed in the grout header assembly at the grout hole. The grout flows are measured by magnetic flowmeters. Information from the grout pressure-take trends obtained by these new instruments provided much better grouting than would have been possible without them. It is probable that, with further

experience in the interpretation of the grout pressure-take trends, the need for expensive uplift-gauge installations could be eliminated, permitting a saving in the cost of rock grouting.

LARGE SCALE EXPERIMENTAL ROCK GROUTING FOR PORTAGE MOUNTAIN DAM P

Benko, K.F.

International Congress on Large Dams, 8th, Edinburgh, 1964, Transactions, vol.1, p.465-493.
Design testing for the initial experimental rock grouting included studies of the site geology, laboratory testing of cements and pozzolans, foundation permeability conditions, investigations of automatic recording and control instruments for field use, and development of grout mixtures.

APPLICATION OF NUCLEAR TESTING TO QUALITY CONTROL OF GROUTING PROCEDURES M

Bernell, L., and Sherman, K.A.

International Congress of Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.1-15.
The nuclear method gives more reliable results than conventional pressure testing shown by experiences including repeated density measurements with the subsurface-type nuclear meter - obtained from soil foundation grouting at the Seitvare Dam.

NUCLEAR RADIATION IN CONSTRUCTION CONTROL OF EARTH AND ROCKFILL DAMS

Bernell, L., and Sherman, K.A.

International Conference on Soil Mechanics and Foundation Engineering, 7th, Mexico City, 1969, Proceedings, vol.2, p.285-289.
Experiences obtained using the nuclear radiation technique have resulted in reliable and simple methods for determining settlements in earth and rockfill embankments and for controlling the effect of grouting in soil and rock.

STRUCTURAL BEHAVIOR OF BHAKRA DAM P

Bhatnagar, P.S., Kapila, I.P., and Sharma, R.P.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.3, p.245-274.
Uplift and seepage shown by measurements. Grouting of the transverse joints has made the structure more rigid and monolithic.

INFLUENCE OF GROUTING ON FLYSCH ROCK PERMEABILITY P

Bilik, Milan

International Congress on Large Dams, 8th, Edinburgh, 1964, Transactions, vol.1, p.757-765.
Permeability and seepage foundation problems in flysch strata rock. Important factors include stratification of permeable and impermeable strata and the inclination and direction of the strata fissures.

THE DOKAN PROJECT: THE FLOOD-DISPOSAL WORKS AND THE GROUTED CUT-OFF CURTAIN P

Binnie, G.M., and others

Institution of Civil Engineers (London), Proceedings, vol.14, p.181-204, 1959, Paper 6390.
Portland cement used to grout cut-off curtain.

MANGLA; PART 1, ENGINEERING OF MANGLA M

Binnie, G.M., and others

Institution of Civil Engineers (London), Proceedings, vol.38, p.337-544, November 1967, Paper 7063 (See especially p.370, Alluvial Grouting Tests; p.371, Bedrock Grouting Tests).
Alluvial Grouting Tests: "Tube a manchette" technique in which an area of alluvium 72 ft deep was enclosed in a "cofferdam" row of groutholes and further grouting done inside. Permeability tests before and after demonstrated that the permeability had been appreciably reduced. A steel-lined shaft, one meter in diameter was sunk through the grouted alluvium and a short way to bedrock. Portholes were provided in the sides of the shaft so that when the covers were removed the grouted bedrock could be inspected. Inspection showed effectiveness of grouting but also fissures in the sandstone bedrock from which an appreciable yield of water was obtained.
Bedrock Grouting Tests: Fissures existed in the bedrock beneath the Mangla Dam Site. Four series of bedrock grouting tests undertaken demonstrated that conventional grouting would be of no value. Permeability results were erratic after grouting from ground level to about 65 ft. About 10 different types of grout were used. Below 65 ft there was some improvement although there were several failures.

THE DEVELOPMENT OF UPLIFT PRESSURES DOWNSTREAM OF A GROUTED CUTOFF DURING THE IMPOUNDING OF THE SELSET RESERVOIR P

Bishop, A.W., Kennard, M.F., and Vaughan, P.R.

Grouts and Drilling Muds in Engineering Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, May 1963, ed. by A.D.M. Penman, p.98-104. London, Butterworths, 1963.

Despite construction of concrete trench and grouting, uplift pressures developed in the rock downstream from the dam.

GROUTING OF THE LIMESTONE FOUNDATION FOR THE ARSTADDALEN DAM P

Bjerrum, L., and Torblaa, I.

Oslo, Norwegian Geotechnical Institute, Publication no.80, p.33-38, 1968.

The paper reviews the foundation conditions for the dam built in Arstaddalen in 1961-1963. The rock was a limestone with relatively serious defects due to its solubility. The details of the grouting job carried out are described and the quantities involved are summarized. The curtain grouting was carried out in two rows of holes. All borings were carried down to a depth of twenty meters and if the water-pressure test of the lowest section exceeded one Lugeon the boring was continued until it had reached compact rock with a water loss of less than one Lugeon. In the grouting the first step was to complete all borings over a length of twenty meters along the axis of the core and to pressure-test them all. The grouting was then started. The grout used was a mixture of cement and water with an admixture of bentonite 2% by weight of cement. When the grouting of the two rows of boreholes was finished a second series of borings was carried out, the so-called control holes, with the purpose of investigating the effect of the grouting on the permeability of the rock. The control holes were located along the dam axis between the grouting holes. The control holes drilled were also grouted. In addition to the curtain grouting a blanket grouting was carried out over the total area where the core was to be in contact with the rock. The purpose of the grout was to extend the sealing work at the surface to greater depth and to fill the narrow fissures and cracks which could not be repaired from the surface. Speaking in more general terms, the blanket grouting is in fact an upper extension of the curtain grouting, increasing the width and the number of borings in the upper and most pervious rock strata where in addition the grouting procedure is restricted by limitations of applied pressure.

BLASTERS DIG SPILLWAY WITH FERTILIZER M

Engineering News-Record, vol.165, no.21, p.44-47,50, November 24, 1960.

Grouting at the Lewis Smith Dam on the Black Warrior River in Alabama--

about 35 miles northwest of Birmingham. A grout curtain was injected along the full length also, and up the abutments to the elevation of the spillway crest. Grout holes were drilled 150 feet deep, with intermediate holes where grout acceptance indicated the necessity. An area fifty feet wide on either side of the curtain was blanket grouted fifteen to twenty feet deep.

VORVERSUCHE UND AUSFUEHRUNG DES INJEKLIONSSCHLEIERS IN MATTMARK P

Blatter, C.E.

Schweizerische Bauzeitung, vol.79, no.42, p.723-728, October 19, 1961; no.43, p.739-745, October 26, 1961.
Preliminary tests of grouted cutoff curtain. Three hundred-twenty ft deep bored curtain under earth dam required extensive testing to provide grout of good workability and pumpability.

ELECTROMAGNETIC OBSERVATIONS OF ANTIFILTRATIONAL CEMENTATION CURTAINS P

Bogoslovsky, V.A., and Ogilvy, A.A.

Geophysical Prospecting, vol.21, no.2, p.296-314, June 1973.
Creation of antifiltrational cementation curtains needed to prevent increased seepage from water reservoirs is labor consuming and costly. The traditional methods of control do not allow observation during process of cementation. The advantage of electrometric observations of cementation currents lies in the possibility of making measurements on the surface from the moment of pumping slurry into a borehole up to the termination of cement hardening. The investigations carried out demonstrate an increase in the specific electrical resistivity in the course of hardening as well as the existence of a functional dependence between the electrical and strength parameters which allows the use of the resistivity method for checking the cement strength.

USE OF THE RESISTANCE METHOD IN CONSTRUCTING GROUT CURTAINS P

Bogoslovsky, V.A.

Hydrotechnical Construction, no.8, p.697-699, August 1969. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.8, p.10-11, August 1969.)
Employs resistance method for geophysical investigations to determine the continuity of grout curtains at a Russian dam site. Grouting used sand-cement grout.

CONSTRUCTION BEGINS ON ASWAN DAM--RUSSIAN STYLE M

Bowman, W.G.

Engineering News-Record, vol.166, no.8, p.32-34, February 23, 1961.
Forward planning for the main dam seems to relate principally to the critical operation of placing the vertical grout curtain. The injections must cover an area about 60 meters wide up and down stream, and must penetrate a compact formation 150 meters below the clay core of the dam. A thinner curtain of grout will also be extended from this level to rock at a depth of 200 meters. Present thinking is that for grouting the fine sand formations a chemical mixed with bentonite will be used. In the coarser sands the grout will consist of 80% Aswan clay and 20% cement.

RECORD GROUT CURTAIN SEALS NILE'S LEAKY BED C P

Bowman, W.G.

Engineering News-Record, vol.180, no.9, p.22-24, 29 February 1968.
Aswan High Dam, Egypt - Grout curtain 835 ft deep, 130 ft thick at top tapering to 16 ft at bottom. Grout impermeable sand and gravel - local Aswan clay and cement used for coarse sand - silicate and aluminate gel used in finest sand - bentonite grout used between the above listed gradations - grouting from bottom up - bentonite, silica lumps, sodium aluminate and hexameta-phosphate (added to clay as a dispersing agent) imported from USSR.

TURKEY'S KEBAN DAM IS DEEPER THAN TALL P

Bowman, W.G.

Engineering News-Record, vol.180, p.78-80, April 11, 1968.
A 1,150-ft-deep grout curtain placed in a shingle pattern safeguards rockfill dam in Turkey. Summarizes main features of this and other Turkish dams.

CONSTRUCTION OF A GROUTED CUTOFF THROUGH A TALUS ZONE P

Brown, E.L., and Comeau, W.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.591-605.
Description of the soil grouting techniques and the construction of a grouted cut-off in talus material extending to a depth of 78 feet below river level and containing large blocks to 10 feet in diameter for the foundations of the north end of the upstream cofferdam at Outardes No.4. Silt, sand and fluvial gravel completely filled the voids between blocks. As an

aid in the selection of initial grout mixes, attempts were made to correlate permeability and grout absorptions. A nomograph for rapid calculation of permeabilities was developed. With a maximum depth to rock 98 feet below the working platform, the completed membrane was 125 feet long. That the grouted cut-off was entirely satisfactory was confirmed by the subsequent excavation to rock immediately downstream of the cofferdam.

LES FONDATIONS DU BARRAGE DANIEL-JOHNSON (MANICOUAGAN 5) (CANADA) P
(THE FOUNDATIONS OF DANIEL JOHNSON DAM (MANICOUAGAN 5) (CANADA))

Brown, E.L., Charalambakis, S., Crepeau, P.M., and Le Francois, P.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.631-650.
Fundamental aspects of design as the geometry of the arches and buttresses and foundation excavation and treatment were governed by the rock structure and problems including joints, shear zones and tension fractures. In French.

ROCK STABILIZATION AT MORROW POINT POWER PLANT P

Brown, G.L., Morgan, E.D., and Dodd, J.S.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.97, no.SM-1, p.119-139, January 1971.
Morrow Point Dam and Power Plant on Gunnison River in Western Colorado; grouting reinforcement bars, rock bolt grouting.

BU REC'S BLUE MESA DAM P

Western Construction, vol.38, no.10, p.56, 61-62, October 1963.
Specialized job-built grouting equipment, specialized techniques for field fabrication and testing of steel penstock liner, and the successful solution of a winter concreting problem highlighted activities at the Blue Mesa Dam on the Gunnison River near Sapinero, Colorado. Tecon has sublet the backfill and pressure grouting of the tunnel liner, as well as the curtain grouting in the dam foundation and abutment areas to a group of specialists who are using an assortment of ingenious rigs and accessories, custom tailored to the job. One of these is a job-built drilling jumbo. Another job-devised refinement is a length of pipe in which the drill steel is inserted and through which the drilling is done. Two additional job-made devices are used in the actual grouting. One is a packer which seats in the 2-inch backfill holes. The other is a pressure gauge saver--a rubber diaphragm cut from a tire tube and designed to keep gauges from being ruined by grout. As a further precaution against clogging of valves and pipes, the subcontractor fits his grout header right on the drill hole--thus minimizing the accumulation of sand when there is a slow take.

DERWENT DAM - CONSTRUCTION P

Buchanan, N.

The Institution of Civil Engineers (London), Proceedings, vol.45, p.401-422, March 1970, Paper 7264.
Rock grouting: Grout mix began with a 29-1 ratio and thickened progressively through 14-1, 7-1, 4-1, 2-1, and 1-1. Some mixtures contained fly ash. Grout not specified but assumed to be either a real slurry or possibly containing sand.

BUILDING LOPEZ DAM P

Western Construction, vol.43, no.1, p.100-101, January 1968.
The San Luis Obispo County Flood Control and Water Conservation District is currently building an earth dam in Lopez Canyon near Arroyo Grande, California. In order to anchor the dam on bedrock, it was necessary to excavate 130 feet below stream bed, and remove some 400,000 cubic yards of sand and debris from this cut-off trench. At this depth, a light grout curtain was then inserted into the foundation to a depth of forty feet, through grout holes at twenty-foot intervals. This grouting will be continued in stages in the cut-off trench all the way to the top of the dam.

BUILDING THE MATHIS DAM P

Engineering News, vol.74, no.12, p.530-532, September 16, 1915.
Underlying rock badly fissured and weathered. About 3,000 feet of holes, 10 to 30 feet deep. Took about 2,300 sacks cement. Grouted under 60- to 90-lb pressure.

CURRENT PRACTICE IN ABUTMENT AND FOUNDATION TREATMENT P

Burke, H.H., Content, C.S., and Kulesza, R.L.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.98, no.SM-10, p.1033-1052, October 1972, Paper 9268.
Construction by Bechtel at Don Pedro Dam, California. Present grouting practice is discussed.

FOUNDATION EVALUATION AND TREATMENT M

Bussey, W.H.

Soil Mechanics Lecture Series: Design and Construction of Earth Structures, sponsored by the Soil Mechanics and Foundation Division, Illinois Section,

American Society of Civil Engineers, and Civil Engineering Department, Illinois Institute of Technology, Chicago, Ill., p.93-118, 1966.

Discusses organization and scope of the appraisal, planning, design, construction phases, pressure testing of drill holes, shaping of foundations and abutments, geological sampling, testing and evaluation, foundation clean-up, blanket and curtain grouting and foundation and abutment drainage.

SOME ROCK-GROUTING EXPERIENCES P

Bussey, W.H.

Grouts and Drilling Muds in Engineering Practice: Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, May 1963, ed. by A.D.M. Penman, p.65-69. London, Butterworths, 1963.

Four case histories of grout curtain construction are described: Karadj Dam, Priest Rapids Dam, Fellows Lake Dam, Puente Viejo Dam.

SUSPENSION GROUTS AND THEIR INJECTION P

Bussey, W.H.

Association of Engineering Geologists, Bulletin, p.313-323, Fall 1973.

The subject of this paper is the construction of impervious cutoffs under dams through the use of suspension grouts. The paper presents the author's observations, opinions and conclusions on some special aspects of grouting not normally covered in state-of-the-art treatments of the subject. Surface geology, cores from drill holes, and results of water pressure tests are the most important guides avilable in planning the grouting program. In addition to refined pressure testing, the electric resistivity log, the borehole camera, and case histories should be used more often in evaluating the grouting problem and estimating lengths of grout holes and quantities of materials required to accomplish the purpose of the grouting program. The natural ground water table is also a useful indicator of subsurface conditions. Important considerations concerning grout holes are that each hole is properly located with respect to other grout holes and to geologic conditions, that the hole be angled to intercept the largest practicable number of joints and fractures and that the walls of the holes be as clean as practicable. Applications to grouting that appear to have great promise are grouting in advance of tunnel driving or boring, grouting for foundations of heavy buildings, particularly nuclear power plants, creation of underground reservoir by constructing a grout curtain barrier across depressions in the water table, and soil stabilization.

ENTRETIEN ET REPARATION DES BARRAGES (REPAIR AND MAINTENANCE OF DAMS) P

Cabaniols, P., and others

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.3, p.307-335.

General conclusions on methods applied for maintaining 230 dams operated by Electricite de France. Dam foundations may need work in the area of grouting and drainage. At Dardennes Dam the masonry was restored by cement grouting through holes deep into the rock so as to form a watertight curtain.

PARAFOUILLES SPECIAUX EN TERRAINS PERMEABLES (SPECIAL CUT-OFF TRENCHES IN PERMEABLE SOILS) P

Cambefort, H.

International Congress on Large Dams, 5th, Paris, 1955, Transactions, vol.1, p.883-896.

Alluvial soils that can be made water-tight from the ground surface downward or from galleries by means of grouting, sheet metal piling, close piles wall, or combined grouting and close piles wall. The grouting is done according to a special technique. It does not permit correct treatment of the superficial layers, and in order to make it really effective the corresponding screen must be thick enough, with at least two lines of grouting. Piling is often not sufficient by itself, especially in slightly permeable soils. The presence of solid blocks or the compactness of the alluvium prevents the piling from being deeply sunk. Their water-tightness must then be completed by grouting. Close pile walls is more universally used than sheet piling. It permits forming flexible or mechanically strong water-tight screening, according to the requirements, and in very deep locations. Combined with grouting, it forms thick solid masses, perfectly watertight up to the surface of the ground. In French with English summary.

SYSTEME DE PUITS ET DE GALERIES EN PROFONDEUR POUR L'EXECUTION DU DIAPHRAGME D'ETANCHEITE AU BARRAGE DE PIAN PALU (SYSTEM OF SHAFTS AND DEEP GALLERIES FOR THE CONSTRUCTION OF THE IMPERVIOUS CUT OFF FOR THE PIAN PADRE DAM) P

Candiani, Giuseppe

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol. 2, p.795-809.

Describes the construction of an impervious cutoff for a concrete block dam. The cutoff consisted of a concrete wall through 72m of river alluvium and extending into the left abutment, plus a grout curtain extending from galleries in the cutoff wall. In French with English summary.

LLYN BRIANNE DAM, SOUTH WALES M

Carlyle, W.J.

Civil Engineering and Public Works Review, vol.64, no.761, p.1195-1200, December 1969.

Joints and faults in bedrock called for grouting. Blanket grouting performed. No grout type mentioned. Grouting performed in holes on 20-ft centers, 1 7/8 in. diam. x 30 ft deep drilled with rotary percussive drills with water flush. Stage grouting is being used throughout.

SHEK PIK DAM P

Carlyle, W.J.

Institution of Civil Engineers (London), Proceedings, vol.30, p.557-588, March 1965.

Earth dam in Hong Kong, grouting of alluvium, weathered rock and moderately weathered rock with cement-bentonite-to-clay mixture.

GROUTING OF FISSURED GROUND C

Caron, C., and Cheylan, G.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.413-429.

Treatment of fissures at Kainjl Dam in Nigeria and Saint-Guilhem-le-Desert in France were treated with chemical grouts. This treatment is very rarely employed in fissured ground as a lean cement grout under pressure can be used.

CONTROL OF SEEPAGE THROUGH FOUNDATIONS AND ABUTMENTS OF DAMS P

Casagrande, A.

Geotechnique, vol.11, no.3, p.161-182, September 1961.

First Rankine Lecture delivered on 25 January, 1961, at the Institution of Civil Engineers. Probably a great majority of the single-line grout curtains in rock foundations and abutments of dams that were carried out in the past were relatively ineffective in reducing seepage losses, and they could not be relied upon for purposes of stability analysis. There is an urgent need for comprehensive observations on the effectiveness of such grout curtains. There is a need for more reliable methods to determine in advance whether and where grouting is needed. On some projects the rate of seepage could be effectively reduced by more economical means than by grout curtains.

PRINCIPLES OF FOUNDATION TREATMENT OF EARTH DAMS

Chaturvedi, M.C.

Journal of the Institution of Engineers (India), Civil Engineering Division, vol.51, no.3, part CI2, November 1970, p.95-102.
Gives test results for grouting of four dams in India.

CHEMICAL GROUT SOLVES DAM ABUTMENT GROUTING PROBLEM C

Construction Equipment, September 1964.
Gechi Dam. Chemical grout injected into rock with fine pore size too fine for normal cement grout. Polymer grout used (AM-9).

LIPTOVSKA MARA DAM P

Chmelar, V.

Inzenyrske Stavby, vol.17, no.3, p.97-108, 1969.
Sealing of foundation formed of alternating thin layers of sandstone and shale by a grout curtain was conducted from a grouting gallery. Grouting tests determined the grouting procedure.

ASPHALT GROUTING FOR WATERPROOFING AND FOR STOPPING LEAKAGE M

Christians, G.W.

Water Works, vol.67, no.6, p.225-226, June 1928.
The stopping of leakage at Columbia Dam (Tenn.); principles of asphalt grouting discussed.

ASPHALT GROUTING UNDER HALES BAR DAM M

Christians, G.W.

Engineering News-Record, vol.84, p.798-802, May 20, 1926.
Hales Bar Dam had been grouted during construction in 1913, but after leakage continued the dam was grouted with asphalt.

UPSTREAM DIAPHRAGM OF SALAGOU DAM P

Clarenc, M.

International Congress on Large Dams, 10th, Montreal, June 1-5, 1970, Transactions, vol.5, p.45-60.

The general layout of Salagou Dam has been described in an article published in a special number of the Review Trevaux published on the occasion of the Ninth International Congress on Large Dams. The dam is built on the River Salagou, a tributary of the Herault. It is an embankment dam, the fill consisting of basalt. It is 60 meters high and 357 meters long at the crest. Watertightness is ensured by an upstream bituminous concrete diaphragm, connected to the grout curtain by a concrete wall.

GEOLOGICAL EXPLORATION AND FOUNDATION TREATMENT, BARKLEY LOCK, CUMBERLAND RIVER, KENTUCKY P

Clark, B.E.

Geological Society of America, Engineering Geology Case Histories, no.4, p.19-25, 1963.
This paper deals primarily with the geological problems encountered at Barkley Lock. Most of the foundation rock was fairly consistent, and problems encountered were relatively minor. The periphery of the cofferdam was grouted in advance of excavation. Cement and sand-cement grout was pumped into 45-degree-angle holes located outside the cofferdam and around the lock excavation. The grouting required about 33,000 feet of grout-hole drilling and 56,000 cubic feet of grout mixtures, consisting of 31,000 bags of cement, 2,000 bags of fly ash, and 23,500 cubic feet of sand. The grout was injected through casing cemented in rock or, in some cases, through a packer set in rock, and under 10 to 80 feet of overburden. Unlike the cofferdam, the lock foundation took almost no grout -- only 145 bags for the two 800-foot-long walls and 110-foot gate sills.

BORING AND GROUTING A FISSURED FOUNDATION BENEATH AN EMBANKMENT DAM

Cole, D.W.

Engineering Record, p.340, March 29, 1913.
Methods used on Lahontan Dam of Truckee Carson Project. Grouting had effect in stiffening adjacent ground so that drilling of secondary subsequent holes was performed with fewer difficulties.

MAKING A CUT-OFF WALL BY GROUTING FISSURED ROCK, LAHONTAN DAM P

Cole, D.W.

Engineering News, vol.69, no.14, p.647-651, April 3, 1913.
The grouting process is described for the construction of the dam. One part of cement is used to eight parts of water. Air pressure of 25 lb was employed for first batches. As the grouting advanced the later batches were driven in at a higher pressure, gradually increasing to 100 lb psi at the finish of each hole.

CONCRETE-FACED ROCKFILL DAM; A SUCCESS STORY IN TASMANIA P

Engineering News-Record, vol.187, no.9, p.23-74, August 26, 1971.
Cethana Dam, on the Forth River in Tasmania, incorporates nearly all of the new design features of concrete-faced rockfill dams: compacted rockfill, thinner concrete face, tight vertical joints and very few horizontal joints, a dowelled cutoff slab, and a simplified copper waterstop. This dam was probably the most carefully watched dam ever during the three months its reservoir was filling. The dam literally bristled with instruments that recorded the most minute changes caused by the rising water. The badly jointed foundation rock was grouted through three rows of holes drilled through the concrete cutoff slab.

GEOLOGICAL PROBLEMS AT ROSS AND GORGE DAMS, SKAGIT RIVER, WASHINGTON

Coombs, A.

International Congress, International Association of Engineering Geology, 1st, Paris, 1970, Proceedings, vol.2, p.1197-1203.
Gorge Dam presented construction problems with a reservoir less than 122 meters from the deep excavation. Groundwater was controlled by a freeze curtain, pump wells, and grouting.

DOWNSVILLE DAM WASTE WEIR FOUNDATION GROUTING;
DOWNSVILLE DAM WASTE WEIR CUT-OFF WALL GROUTING

Cooper, J.H., and Fluhr, T.W.

Delaware Water Supply News, vol.13, p.737-741, 1951; vol.15, p.781-785, 1953.

CONDITIONS GEOLOGIQUES ET MICROTECTONIQUES DU SITE DE BARRAGE DE POIANA UZULUI. INFLUENCE SUR LA PERMEABILITE ET SUR LA CAPACITE D'INJECTION DES ROCHES (GEOLOGICAL AND MICROTECTONIC CONDITIONS OF THE POIANA UZULUI-DAM SITE AND THEIR INFLUENCE ON PERMEABILITY AND GROUTING OF THE BEDROCK) P

Craciun, F., Moisescu, S., and Ghika, M.

International Association of Engineering Geologists, International Congress, 1st, Paris, 1970, Proceedings, vol.2, p.1102-1112.
Fractures and fissures in the sandstones of the foundation rock of the Poiana Uzului concrete dam in Rumania were mapped in detail. Tectonic conditions were related to the results of the permeability tests and the grouting work. In zones with small tectonic separation the grouting capacity is remarkably less than in greatly disturbed zones. In French.

PERFORMANCE RECORD OF WALTER F. GEORGE LOCK AND DAM

Crisp, R.L.

Specialty Conference on Performance of Earth and Earth-Supported Structures, Lafayette, Ind., Purdue University, June 11-14, 1972, Proceedings, vol.1, part 1, p.691-702. New York, American Society of Civil Engineers, 1972.
The conclusion was reached that remedial treatment such as grouting cannot be dependended upon as a permanent treatment. Remedial treatment such as the recent caverns found at an elevation above previous grout takes is too expensive. Including construction grouting, relief wells, remedial grouting and various type investigations, approximately 6 million dollars have been spent on foundations at this lock and dam.

THE DETERIORATION OF CONCRETE DAMS FORTY YEARS' EXPERIENCE IN NORTH WALES

Crosthwaite, C.D., and Hunter, J.K.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.3, p.207-226.
Contains a 2-page description of pressure grouting at Maentwrog Dam (p.216-217).

CUT-OFF WALL AND ROCK GROUTING AT THE MILTON RESERVOIR EMBANKMENT

Engineering News, vol.73, no.10, p.468-470, March 11, 1915.
Upstream cut-off wall at steel sheet piling excavated on one side showing failure was backfilled with a 30-inch concrete wall through which grouting pipes extended to rock strata in bottom.

THE SEALING UP OF DAMS MADE OF EARTH AS WELL AS OF EARTH AND ROCK FILLING IN THE CONDITIONS OF CARPATHIAN FLYSCH P

Czyzewski, K., Skrzynski, J., and Wolski, W.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.4, p.441-465.
Dam foundations on anisotropic and stratified layers of sandstone and clay shale were sealed by grouting.

WANAPUM DAM'S INGENIOUS CONSTRUCTION M

Day, R.

Excavating Engineer, vol.55, no.5, p.14-20, May 1961.

One of the most ingenious solutions to a problem has been the use of a new slurry method on the impervious core. It allows a watertight curtain of clayey material to be placed without dewatering the area. Slurry equipment consisted of three portable plants, with a mixing capacity totaling fifteen barrels per minute. The slurry mixture was simple--one part bentonite to twelve parts of water. Mixing in the plants was done by water jets and the mixed slurry was then pumped through eight-inch pipelines to a 10,000-barrel sump, where it could then be routed to the trench. Because the specific gravity of the slurry is higher than that of ground water, maintenance of a full trench of solution prevented water from pouring into the excavation. Even at bedrock, water was held back. The heavy slurry also preserved the vertical walls. To prevent sand dilution of the slurry, it was kept fresh by recirculating it through sumps. Impervious clay was dumped from the surface, working the dump only a short distance behind the excavation point. Every effort was made to prevent any dilution of the slurry with this material. Final result was a dense close-knit wall of impervious earth, bolstered on either side by slurry-reinforced overburden. The core wall is being built fast, free of ground water without excessive excavation, and without having to fight an impossible water pumping problem.

WATERPROOFING AT THE GUADALHORCE-GUADALTEBA DAM

De Cossio, Luis

International Congress on Large Dams, 11th, Madrid, 11-15 June 1973, Transactions, vol.4, p.889-904.
This paper studies the constructive process of the system of waterproofing and of the result obtained at the Guadalhorce-Guadalteba Dam, a rockfill dam with central impervious clay core.

GROUTING OF MASONRY DAMS

Derqui, F.C.

Congress on Large Dams, 2nd, Washington, D.C., Transactions, vol.5, p.489-492, 1936.
Discusses disposition of holes, grouting pressure, and intermittent injecting flow pressure.

PEACE RIVER PROJECT P

Des Champs, J.S.

Engineering & Contract Record, vol.77, no.10, p.43-55, September 1964.
A massive earthfill dam will form the backbone of the Peace River Hydroelectric Project in Northern British Columbia, 500 air miles north of Vancouver. Blanket grouting of the core contact zone and the establishment

of a deep grout curtain will act in conjunction with the gunite as a sealing link between the bared rock and the dam fill material. The grout blanket which will cover the core-contact zone will be ten to fifteen feet deep at the up- and downstream-limits with an intermediate depth of about 25 feet. In the area of the grout curtain the blanket will be at a sixty-foot depth. The blanket grouting will require approximately 20,000 holes. The blanket grout material consists of various percentage mixtures of cement, pozzolan, water and colouring agent. The colouring agent aids in detecting, by means of a borehole camera, the relative position of the grout after it is in the rock. About 270 feet upstream from the main axis of the dam and stretching across the river bed, a grouting culvert has been excavated to facilitate work on the grout curtain. The culvert will enable crews, working inside to carry on the curtain work while fill is being placed above their heads. The principle work will be the construction of a multiple-line grout curtain in the sedimentary-type bedrock foundation, to be 300 feet deep at its deepest point. It will require drilling 250,000 linear feet of 1 1/2-inch diameter grout holes and injecting approximately 1,000,000 cubic feet of portland cement and pozzolan mixtures at pulsation-free pressures of up to 750 psi.

STRENGTHENING THE CONCRETE DAM AT KOYNA M

Deuskar, V.R., and Bhalerao, S.M.

Indian Concrete Journal, vol.47, no.5, p.178-185, May 1973.
The Koyna Dam, a concrete gravity structure, was relatively unharmed in the earthquake of 1967. Strengthening measures included grouting of all cracks with epoxy resin, guniting the areas adjoining the cracks, and strengthening some of the monoliths by prestressing.

REVIEW OF SOME RECENT DAMS BUILT FOR SCOTTISH CONDITIONS

Dickerson, L.H., and Morton, R.R.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.3, Question no.26, p.320-341.
This paper contains a brief section on grouting of the Scottish dams. In most cases, the curtain grouting has been sufficient to ensure a tight up-stream cut-off, as the sites are relatively free from soft-filled seams and fissures.

INVESTIGATIONS AND PERMEABILITY FOUNDATION TREATMENT AT THE SITE OF THE PROPOSED GUMA DAM, SIERRA LEONE P

Dixon, H.H., and Perrott, W.E.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.4, p.109-128.

Describes the investigations into the foundations of the proposed Guma Dam and the grouting which was undertaken before construction was started. The bedrock at site consists of gabbro intruded by dolerite dykes with considerable lateritic weathering. The cut-off curtain in unweathered rock was formed with cement grout, and the lateritic weathered rock was treated with clay-cement grouts. The results of permeability tests before and after treatment are compared. Grout consumptions for the various portions of the work are given.

GROUTING THE JOINTS OF THE KRASNOYARSK HYDROELECTRIC-STATION DAM

Dolmatov, A.P., Pavlov, V.L., and Plosk, A.E.

Hydrotechnical Construction, no.7, p.601-607, July 1970. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.7, p.11-15, July 1970.)
In the concrete gravity dam of the Krasnoyarsk Hydroelectric Station, the intercolumn joints formed by cooling of the placed concrete must be grouted. The grouting system is of the closed type; hence it is impracticable to wash it out after grouting, and consequently it can be used only once. Especially important during the grouting operation is the maintenance of operating conditions, aimed at limiting pressures and deformations. Owing to defects in the system the grouting of a small number of panels was effected through drilled holes. The quality of the grouting depends, to a considerable degree, on the size of the joint opening. The constructional decision adopted for preparation of the placed concrete for the dam and for rendering it monolithic made it possible to carry out properly-timed grouting of the structure. It is expedient to stipulate the distance between joints as not less than 13 to 15m.

BURRENDONG DAM CONSTRUCTION P

Douglas, A.W.

Institution of Engineers, Australia, Civil Engineering Transactions, vol.CE7, no.2, p.49-62, October 1965.
Grout curtain holes 15 ft with 5 centers 100, 200 ft of grout holes drilled. "Take" was 0.25 cu ft cement per ft of grout hole. Grout was portland cement and water. Water cement ratios varied from 3 to 1 for starting grouts to 1 to 1 for finishing grouts.

MCNARY DAM - DESIGN FROM TECHNICAL CONSIDERATIONS P

Drake, H.L., and others

American Society of Civil Engineers, Proceedings, vol.81, Proceedings Separate no.787, September 1955.

The test grouting program at McNary Dam indicated that the more pervious portions of the interbed could not be grouted with very thin cement grout and highest feasible pressures. On the other hand, it was determined that the artesian horizon could be successfully grouted at 50 to 350 psi, water cement ratios varying from 0.9 to 5.0, by volume, and grout holes on 5-foot centers. It was considered necessary to provide a single grout curtain and drainage under all the concrete structures. The grout curtain was designed to extend to top of interbed and the drain holes were to extend to 1/3 of that depth.

DUKE POWER MATES NUCLEAR, HYDRO, PUMPED STORAGE PLANTS P

Engineering News-Record, vol.190, no.3, p.24-25, January 18, 1973.
Duke Power Company's $700-million Keowee-Toxaway Project, in Northwestern South Carolina near Clemson represents the perfect blend of nuclear, conventional hydro and pumped storage. The three generating sites in the project are the Jocassee Dam on the Keowee River, the Oconee Nuclear Generating Station and Keowee Dam. Jocassee required the most extensive foundation preparation of the three dams. Cement grout was injected in underlying rock strata through 3-inch holes drilled in two rows 10 feet apart and as deep as 150 feet to intercept as many joints as possible. Holes were first drilled on 10-foot centers, with subsequent drops to 5 and 2.5-foot centers when grout takes called for it. The same stepping procedure was followed then to install a single-line injection of chemical grout between the two cement grout curtains. Any cracks in the core area were also slush grouted to ensure water-tightness. A total of more than 50,000 sacks of grouting material were required; 46,750 of cement, 4,200 of chemical grout. Because of sounder rock encountered at the sites of Keowee and Little River Dams, little grouting was necessary for either dam. Keowee required only a single curtain of cement grout placed through holes drilled 10 feet deep, while a single row of 10-foot centers drilled 75 to 100 feet deep was used on the Little River foundation.

SELECTION OF CHEMICAL GROUT FOR MATTMARK DAM C

Einstein, H.H., and Schnitter, G.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.96, no.SM6, p.2007-2023, November 1970, Paper 7684.
One of the main problems at Mattmark Dam (Switzerland) was sealing the underlying soil which consisted of layers of strongly different properties reaching a depth of 100 m over bedrock. The soil had to be sealed by a grout curtain. A multiple-stage grouting procedure was chosen with the last stage using a chemical grout.

CONSTRUCTION OF THE PLOVER COVE DAMS

Elliot, S.G., Ford, S.E.H., and Oules, J.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.4, p.85-110.
Contains one page on the cut-off grouting used in dam construction.

POMME DE TERRE DAM OF EARTH AND ROCKFILL P

Elser, L.G., and Schuster, D.E.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, no.SM1, p.67-94, February 1963, Paper 3418.
The Pomme de Terre Dam which is located in Central Missouri, has a composite embankment section with an upstream rolled earthfill and a downstream rockfill shell. The paper is devoted principally to the earthwork and foundation design and construction. Special features include placement of quarry-run rockfill "dry" in five-foot lifts, using lower quality rockfill in the upstream drain to facilitate consolidation of the clay foundation, and pore pressure devices in embankment and foundation clays. Seepage through bedrock was controlled by a grout curtain extending the entire length of the valley embankment. Reservoir storage above the spillway crest would be of short duration; hence complete cutoff of underseepage above the spillway elevation was not considered necessary. A three-foot-deep inspection trench was provided above this crest elevation and under the dike. Contact grouting was effectively sealed with clay fillings and mineralization.

PURPOSE OR NEED FOR GROUTING IN THE TREATMENT OF FOUNDATIONS M

Elston, J.P.

Inspection, Maintenance, and Rehabilitation of Old Dams; Proceedings of Engineering Foundation Conference, Pacific Grove, Calif., September 23-28, 1973. New York, American Society of Civil Engineers, 1974.
Discusses the types of foundation material and the need for grouting in the construction of dams.

INNOVATIONS AT WANAPUM DAM P

Engstrom, U.V.

Civil Engineering, vol.33, no.10, p.43-47, October 1963.
For depths ranging from zero up to 80 ft in water-bearing river gravels the impervious cutoff was effected by utilizing the slurry trench method for excavation. This method proved very successful and was economically performed to the required depth of 80 ft. In two areas it was necessary to

go to depths greater than 80 ft to reach rock. Here a unique system of grouting the "open work" gravels was used. After the slurry trench had been completed and a few feet of protective embankment placed over the trench, drill rigs were moved in and the grout program started. The objective was to grout the gravels in a pattern of three rows of holes parallel with the trench. Rows were 3 ft apart and the holes in the rows were 6 ft on centers. The sequence was to grout the upstream row first, the downstream row next, and alternate holes in the center row last. The remaining holes in the center row were used as check holes and were grouted if it was found to be necessary.

FOUNDATION PROBLEMS IN KEBAN DAM AND THE CUTOFF WALL P

Esen, T., and Seyhun, S.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.811-826.
Describes treatment and grouting methods used in different sections in the construction of the largest rockfill and concrete gravity dam in Turkey. Foundation rock is extremely karstified metamorphic limestone and marble underlaid by almost impervious schist.

E.T.F.E. MEMBRANE GROUTING PROCESS P

Water & Water Engineering, vol.67, no.809, p.283-284, July 1963.
Intake works at Diddington Reservoir. Scheme uses new method of constructing water-tight barrier developed by Etudes et Travaux de Fondations, Toulosse, France for first time in Great Britain.

SHEAR STRENGTH OF JOINTS IN ROCKS BEFORE AND AFTER GROUTING P

Evdokimov, P.D., Adamovich, A.N., Fradkin, L.P. and Denisov, V.N.

Hydrotechnical Construction, no.3, p.229-232, March 1970. (Translated from Gidrotekhnicheskoe Stroitel'stvo, no.3, p.26-30, March 1970.)
Cement grouting of fissured ledge rocks leads to a marked reduction in slip deformation due to an inclined load. The effect of cementation is most marked in badly fractured rocks, the slip of which in the natural state is characterized by an elongated horizontal-displacement graph. Cement grouting leads to an increase in the shear strength of hard rocks. Cementation is most effective in badly fractured rocks without fine earth filling, owing to the efficient filling of the cracks by the cement solution. The use of cement solutions based on dispersed cement (colloidal cement or dry-vibromilled cement) permits cement grouting to be more effective than with ordinary cement. The presence of badly broken sections in a rock foundation is not necessarily a reason for reduced slip resistance parameters or for removal of much of the rock and in such cases we should always consider whether it is advantageous to use cement grouting to improve the quality of the rock.

EXPERIMENTAL GROUTING AT MORROW POINT DAM WITH CATIONIC ASPHALT EMULSION M

USCOLD (U.S. Committee on Large Dams) Newsletter, no.32, p.11-12, May 1970.

Leakage at Morrow Point Dam in West Central Colorado through left abutment at full reservoir head. Exploratory drilling showed leakage outside the perimeter of a previously grouted (cement) cut-off curtain. Cationic asphalt emulsion, a stable suspension of minute particles of asphalt in water, was chosen for grouting of the leakage at elevation 6965 on left abutment. Grouting was accomplished with a duplex piston type pump. An asphalt emulsion injection was followed by a lime slurry injection and a 65% reduction in leakage was obtained. Some conclusions were: (a) Cationic asphalt emulsions proved to be effective in reducing large leakage through the abutment of the dam; (b) Injection of the emulsion from pressure tanks in lieu of pumping equipment is recommended; (c) The injection operations should be continuous and without interruptions; and (d) The proportioning of emulsion to lime slurry is very important, and should be pre-tested before injection.

EXPERIMENTAL STUDIES ON SEEPAGE FLOW IN ARCH DAM FOUNDATION P

Japan, Society of Civil Engineers, Transactions, no.97, p.13-40, September 1963.

Study of grout curtain conducted when partial filling of reservoir was completed; investigation of drainage system served as basis for design work.

ETANCHEMENT D'UN BARRAGE EN TERRE AU MOYEN D'INJECTIONS DE CIMENT SOUS RETENUE NORMALE DE L'EAU (LIMITATION OF LEAKAGE THROUGH AN EARTH DAM BY MEANS OF CEMENT GROUTING UNDER NORMAL WATER HEAD) P

Fanti, K., and others

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.3, p.739-50.

Ground grouting at an earth dam is described. Grouting was conducted at normal water level of the reservoir during continuous work of power station. After grouting was completed, no leakage and settlements were observed.

FARAHNAY PAHLAVI DAM P

Consulting Engineer, vol.30, no.8, August 1966.

Formerly the Latiyan Dam. Located north-east of Tehran (Middle East) Soletanche of Paris performed grouting. Grout curtain and consolidation grouting performed.

TESTING THE EFFICIENCY OF GROUTING OPERATIONS AT DAM SITES

Ferguson, F.F., and Lancaster-Jones, P.F.F.

International Congress on Large Dams, 8th, Edinburgh, 1964, Transactions, vol.1, p.121-140, Question no.28, Response no.7.

LES VOILES O'INJECTION DU BARRAGE DE LIMMERNBODEN (GROUT CURTAINS OF THE LIMMERNBODEN DAM) P

Forces Motrices du Nord-est de la Suisse, S.A.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.101-121.
Construction of grout curtain along the right flank of the valley and the main grout curtain which was considerably extended and jointed to the right flank for the Limmernboden Dam. The pervious nature of the rock was established by test drillings and dye tests. In French.

THE FRENCH HAVE A WAY WITH GROUT CURTAINS P

Engineering News-Record, vol.170, no.17, p.32-33, 25 April 1963.
A French contractor builds grout curtains fast and economically using a process that pumps grout down a pipe welded in the fillet of each beam so that the grout fills the void left by the beam as it is extracted. The moving steel wall leaves behind a wall of cement grout averaging eight to ten inches in thickness and up to three feet thick in highly permeable stratum. The contractor uses a set of seven grout beams, rolled sections reinforced with steel plates at the lower end. A rivet plugs the end of the grout pipe while the pile hammer sets the beam. Grout injection blows out the rivet as extraction begins. Grouting pressures are kept high enough that the volume of grout injected is four to five times the volume opened up by the web of the beam as it is extracted. A clever, surprisingly small rig drives a beam on one end, while the beam-out-grout-in operation goes on at the other end.

SUBSOIL EXPLORATION FOR ZERVREILA ARCH DAM BY MEANS OF BORINGS, EXPLORATORY TUNNELS AND CEMENT INJECTIONS IN BEDROCK P

Frey-Baer, O.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, Question no.25, p.261-267.
The groutings for sealing up the bedrock at damsite were carried out in two series. After completion of the excavations a grout screen was built. The groutings between the rock and the concrete mass of the dam could only be carried out after the blocks of concrete had reached a height of at least 10 m.

CONTROL AND MAINTENANCE OF CONCRETE STRUCTURES ON EXISTING DAMS IN SWEDEN M

Fristrom, G., and Sallstrom, S.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.3, p.383-401.
Sealing of leaking cracks and joints. Plastics have come to be used for this type of repair. Epoxy resin has been shown to have suitable properties for repairs on concrete. The epoxy system which has been mostly used for concrete repairs on the basis of test results, utilizes an anilineformaldehyde type hardener. Also used is a polysulphide type plasticizer and in certain cases reactive solvents of the type polyethylene glycol. Sealing is performed either by coating surfaces or by injecting resin as a grout.

FOUNDATION GROUTING AT NAGAWADO DAM

Fujii, Toshio

International Congress on Large Dams, 10th, Montreal, 1-5 June 1970, Transactions, vol.6, p.747-768.
This paper gives an outline of the design and the construction of the foundation grouting, especially the curtain grouting, at Nagawado Dam. Nagawado Dam is 155 m high.

CAVERNS UNDER DAM CORE WALL SET NICE REPAIR PROBLEM

Gannet, F.

Engineering News-Record, vol.116, no.14, p.492-494, April 29, 1936.
Water finds cavern that grouting missed and scours inlet under dike and core wall of Ontelaunee Dam near Reading, Pa.

LUNERSEE DAM; SEALING OF THE RIDGE CLOSING THE LAKE BASIN P

Ganser, O.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.277-286.
Leakage reduced by sealing ridge with cement grouting and concrete plugs. Extensive cement grouting was performed, sometimes extending to great depths, after the removal of loose material and washing down of the rock surface with water under pressure for the dam at the Lunarsee Power Plant.

CUTOFF AND STABILITY MEASURES FOR A DAM ON SAND FOUNDATION C, P

Garg, S.P., and Agrawal, R.K.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.1069-1088.
Seepage occurring at Obra. A complete cut-off to rock was adopted. The cutoff is two 0.6 m thick cast-in-situ reinforced concrete walls 3 m apart, with the intervening sand grouted. Other grouting operations are also referenced in this article (cement and chemical.)

METHOD OF GROUTING ROCK FOUNDATIONS OF DAMS AT HARTFORD, CONN.

Garrett, J.E.

Engineering and Contracting, vol.50, p.36, July 10, 1918.

EXPERIMENTAL CATIONIC ASPHALT EMULSION GROUTING M

Gebhart, L.R.

American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division, vol.98, no.SM9, p.859-868, September 1972, Paper 9172.
Large flowing water channel was plugged by a cationic asphalt emulsion grout which was triggered by a hydrated lime slurry. Leakage was around the limits of the cement grout curtain and into the underground power plant drainage tunnel.

HIGH EARTHFILL DAM FOUNDATION GROUTING DESIGN AND CONSTRUCTION PROCEDURES

Gebhart, L.R.

American Society of Civil Engineers, National Meeting Water Resources Engineering, New Orleans, La., February 1969.
The general plan for grouting the hypothetical dam provides for shallow low-pressure blanket grouting to fill voids in the limestone near the surface to protect the dam embankment. Two deep, high-pressure grout curtains will provide a cutoff and increase the percolation path under the dam.

BACKWATER DAM, ANGUS C

Geddes, W.G.N.

Civil Engineering and Public Works Review, vol.64, no.760, p.1127-1130, November 1969.

Grout curtain utilizing clay cement, deflocculated bentonite, and silicate-aluminates (560,000 cu ft grouting injected). Also 750 tons cement injected into fissures in the rock strata. A requirement of 1 x 10 cm/sec for permeability was set as the requirement after grouting. This result was invariably obtained. Subsequent readings indicate that this curtain is proving effective.

BACKWATER DAM IN THE COUNTY OF ANGUS, SCOTLAND, GROUTED CUT-OFF C, P

Geddes, W.G.N., and Pradoura, H.H.M.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.253-274.

Clay-cement deflocculated bentonite and silica-based grout (silica aluminate) were used to grout a cutoff curtain to bedrock. General details are given of the mixing and injection arrangements for the grout, the rate of injection of the different grouts in the strata and the results of various tests.

GEOLOGY AND FOUNDATION TREATMENT, TENNESSEE VALLEY AUTHORITY PROJECTS C, P

Knoxville, Tennessee, Tennessee Valley Authority, Technical Report no.22; Washington, U.S. Government Printing Office, 1949.

This is the second of a special technical report recording the experience of the Tennessee Valley Authority in carrying out the major phases of its engineering and construction program. This report covers the general subject of foundations for dams and related structures and comprises a record of the more important facts concerning the geology and the foundation treatment required in the construction of the major water control structures of the Tennessee River System. A more detailed coverage of the newer and more unusual features and methods has been given with relatively less description alloted to these phases of the work which followed established engineering practice. The report is presented chiefly from the points of view of the geologists and the construction organization. After introductory statements as to the geology of the region and a discussion of methods and equipment involved in foundation treatment and preparation, the geology and remedial treatment of foundations for the various projects are described in some detail.

LES INJECTIONS DANS LES ALLUVIUMS ET DANS LE ROCHES DE LA FONDATION POUR LA DIGUE DE MATTMARK (ALLUVIUM AND BEDROCK GROUTING FOR FOUNDATIONS OF THE MATTMARK DAM) C

Gerber, F.P.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, p.459-472.

Grouting tests and operations for rockfill dam at Mattmark Hydroelectric Development located in the Upper Rhone Valley of Switzerland. Special grouting with clayey materials and chemicals were required in order to render impervious the foundation ground. Grouting tests were carried out in order to study possibilities of grouting morainic and alluvial terrains and to determine the quantities and mixes of grouting materials (clay, cement, bentonite and chemical products.) Special pressure tests were made in order to avoid ground-rupture which is considered most undesirable in the Mattmark case. The methods adopted for the grouting tests as well as the amount of grouting material and the pressures attained are described for each phase of the grout test. The results of the tests are summarized in the final conclusions. The reasons showing that ground-rupture is undesirable are proved through experiences gained during the grouting tests. In French.

OBSERVATIONS OF DEFORMATIONS IN THE FOUNDATIONS OF THE RINCON DEL BONETE DAM ON THE RIO NEGRO (URUGUAY) AND THEIR RELATION WITH THE LEVELS OF THE RESERVOIR AND THE RIVER: PART IV. - BEDROCK GROUTING FOR IMPERVIOUS CURTAINS AND CONSOLIDATION C, P

Giavi, C.A., and Salles, Manuel

International Congress on Large Dams, 6th, New York, 1958, Transactions, vol.2, Question no.21, p.256-263.
Discusses techniques of cement and chemical grouting of foundation bedrock of Rincon del Bonete Dam in Uruguay.

DIGUE ET ECRAN D'INJECTION DE MATTMARK (MATTMARK DAM AND GROUT CURTAIN)

Gilg, B.

Houille Blanche, no.5/6, p.487-493, 1973.
Special features of the Mattmark Dam are: (a) Core consisting of relatively pervious moraine material containing few fine particles; (b) Backfill over a thick layer of loose ground treated by grout injection. Studies were made of the special backfilling operations and grout injections in loose ground and rock, and the dam and grout curtain were probed both during construction and for ten years after the project was commissioned. In French.

ERDBAUMECHANIECHE PROBLEME BEI DER PROJEKTIERUNG UND BEIM BAU DES STAUDAMMES MATTMARK (EARTHWORK MECHANICAL PROBLEMS IN DESIGNING AND BUILDING MATTMARK EARTH-DAM) P

Gilg, B.

Schweizerische Bauzeitung, vol.83, no.11, p.169-178, March 18, 1965.

Foundation rests on valley floor formed by 100 m deep alluvial deposit and moraine debris strata; injection of deep grout curtain into floor was required. Text in German.

THE GROUTING CURTAIN OF MATTMARK DAM (SWITZERLAND) C, P

Gilg, B.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.171-190.
Treatment for the principal grout curtain at Mattmark Dam carried out in three stages - the first two using a clay cement grout and the third a mixture of bentonite and silicate. The permeability of the treated ground was determined by regular pumping and water level tests.

DAS PROJEKT DES DICHTUNGESSCHIRMES IM STAUDAMM VON MATTMARK (SEALING CURTAIN OF MATTMARK DAM) P

Gilg, B.

Schweizerische Bauzeitung, vol.79, no.35, p.609-613, August 31, 1961. Text in German.

LE VOILE D'INJECTION DU BARRAGE DE PUNT DAL GALL (GROUT CURTAIN OF PUNT DAL GAL DAM, ITALY) P

Gilg, B.

International Society for Rock Mechanics, 2d, Belgrade, 1970, Proceedings, vol.3, p.223-232, Theme 6, Paper no.14.
Because the dam was situated in a highly tectonic and torn up dolomitic mountain zone, intensive treatment of the underlying rock was necessary. The grout curtain reaches 120 to 180 meters below the foundation level. Concrete was injected into boreholes in five injection phases, three of which included additional permeability tests. In French.

SULLA IMPERMEABILIZZAZIONE DELLA ROCCE DI FONDAZIONE DEGLI SBAVRAMENTI

Gnisci, V.

Giornale del Genio Civile, vol.100, no.2, p.125-148, February 1962.
Treatment by grouting of permeable foundation of dam; characteristics of 40 waterproof curtains are given.

IMPERMEABILISATION, DRAINAGE ET AUSCULTATION SIMULTANEES DES FONDATIONS (WATERTIGHTENING, DRAINAGE, AND SIMULTANEOUS INSPECTION OF THE FOUNDATIONS) P

Gomez Laa, G., and Alonso Franco, M.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.559-572.
Discusses the effectiveness of the deep vertical grouting screen versus the impermeable horizontal apron for preventing seepage through dam foundations. Recommends an adequate system of inspection and working galleries in dam projects. In French with brief English summary.

USE OF GROUT IN CUT-OFF TRENCHES, AND CONCRETE CORE WALLS FOR EARTHEN EMBANKMENT P

Gourley, H.J.F.

Engineering, vol.114, no.2973, p.812-815, December 29, 1922.
Discusses various grouting schemes used in the construction of dams and other hydraulic structures.

THE FOUNDATIONS OF THE NEW CROTON DAM

Gowen, C.S.

American Society of Civil Engineers, Transactions. vol.43, no.1, p.1-72, 1900.
Discusses the "painting" of the rock bottom with grout of neat portland cement to fill all small open cracks, seams, and erosion during the construction of the New Croton Dam near New York City.

SUMMARY - FOUNDATIONS FOR DAMS P

Graf, E.D.

Foundations for Dams, An Engineering Foundation Conference, Pacific Grove, California, March 17-21, 1974. New York, American Society of Civil Engineers, 1974.
Gives a brief summary of American and European practice in dam grouting.

GROUTING A DAM CUTOFF IN CAVERNOUS LIMESTONE P

Grant, L.F., and Winefordner, J.S.

American Society of Civil Engineers, Journal of the Construction Division,

vol.92, no.CO3, p.1-15, September 1966, Paper 4894.
Cutoff treatment at Logan Martin Dam was important in providing a stable and watertight foundation. Complex cavity systems occurred in the fractured dolomitic limestone bedrock. Massive filling required to retard serious leakage. Grouting also required in weathered parts of the foundation. Neat cement grout used in some instances. In other instances various fillers were tested. These included local clays, sand, rock dust and fly ash. A large amount of rock dust and fly ash was actually used.

CUT-OFF IN DEEP DEPOSITS OF PERVIOUS MATERIALS AND THEIR EFFECTIVENESS P

Groner, C.F., and others

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.757-765.
Permeable moraine deposits. Cut-off established. A grout curtain was constructed. Combinations of clay, cement, sodium, silicate and phosphate were used.

GROUT CURTAIN UNDER SWISS DAM COSTS $5 MILLION C, M, P

Engineering News-Record, vol.173, p.28-29, November 26, 1964.
Grouting pattern, procedures, and pressures for pressure grouting with clay/cement mixture, bentonite and chemicals for the Mattmark Dam in the Swiss Alps.

GROUT HOLES DRY UP LEAKY DAM C

Construction Methods and Equipment, vol.49, no.11, p.13-14, 16, November 1967.
A troublesome leak due to rainwater seepage into the superstructure of a New York State Dam was stopped by injecting a chemical sealant through holes drilled in the face of the dam. The water was not from the reservoir, but from a surface water that penetrated a copper waterstop five feet inside the upstream face of the dam. To plug the leak the contractor had to drill holes at regular intervals along the face of the dam and fill them with a pumpable grade of Thiodol polysulphide sealant. Drilling was completed in seven working days. The subcontractor used a lightweight electric drill to sink eight holes just below the upstream crest of the spillway. Next, the drillers worked from scaffolding suspended at the two wings of the dam to drill five holes in each wing. At all points the drillers wore safety gear, including lifelines to a special cable between roadways on the wings. All holes were drilled downward at an angle of about thirty degrees into the vertical construction joints between the structures monolithic segments. Flakes of copper boiling out with the coolant water indicated that the copper water-stop was being penetrated.

GROUTING SYSTEM PLACES 100-FT-DEEP CUTOFF WALL P

Engineering News-Record, vol.192, no.18, p.16, May 2, 1974.
A Japanese company is building soil cement underground cutoff walls with a system it calls jet grouting. Three concentric pipes form the basis of the system, which simultaneously ejects an air-water jet and grout. The technique is especially useful for building temporary cutoff walls in situations that will not allow driving piles or conventional slurry wall construction. The technique can be used in most clays, silts, sands and soils containing gravels up to 4-in-diameter. The grout, a mixture of cement, water and bentonite, discharges from the pipe seven inches below the air-water jet, at 40-50 gpm. The compressed air and slurry mixture fills the slit, reaches the secondary guide hole and forces its way to the surface. Control of the air curtain around the water jet is the key to the process. The protection of the air curtain allows the jet water to maintain the same pressure as it would in open air. The volume of water must be carefully controlled in order to maintain sufficient soil content in the slurry so it will support the slot's walls.

GROUTING THE OLIVE BRIDGE DAM

Engineering Record, p.385, April 8, 1911.

GROUTING THE POROUS FOUNDATIONS OF A DAM P

Engineering News-Record, vol.66, p.754, 1911.
An attempt was made to improve a very porous foundation of a dam by pumping grout into drill holes driven through the clear rock bottom.

THE ASPHALT SEALING MEMBRANE OF THE DAM OF LECH POWER PLANT PREM M

Gsaenger, A.

International Congress on Large Dams, 11th, Madrid, 11-15 June 1973, Transactions, vol.3, p.265-280.
The watertight connection of the narrow grout wall to the asphaltic slope lining with the aid of dense plastic asphalt was successful.

TRAVAUX D'ETANCHEMENT ET DE-TRAITEMENT DES TERRAINS DE FONDATION DU BARRAGE DE BIN EL OUIDANE P

Haegelen, A.

International Congress on Large Dams, 5th, Paris, 1955, Transactions, vol.1, p.417-441.

Lateral curtains were adopted which extended the normal water-tight curtain placed beneath the dam into the two banks which kept the amount of grouting within reasonable limits. Consolidation and high pressure grouting operations are described.

GROUTING DEEP ALLUVIAL TILL IN DURANCE RIVER VALLEY, SERRE PONRON DAM, FRANCE P

Haffen, M.

Geological Society of America, Engineering Geological Case Histories, no.4, p.33-44, 1963.
Watertight grout curtain constructed to bedrock to protect against excessive ground water leakage.

KARAOUN DAM STUDY OF THE WATERTIGHTNESS AND IMPROVEMENTS; RESULTS OBTAINED DURING THE FILLING P

Halwani, Salah, and Petiteville, P.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.1123-1141.
The Keraoun dam is located on the Litani River, at the southern end of the plain which separates Lebanon from the Anti-Lebanon. The site of the dam and reservoir is mainly composed of more or less karstic limestone. Owing to the risk of extensive leakage, which might not have been sealed, the dam was constructed in several stages. It is a rockfill structure with an upstream concrete facing. With these arrangements, partial fillings could be carried out, and the execution of each phase was only decided after the hydrogeological information constituting an adequate guarantee for the following phase had been obtained. The setting-out of the grout curtain took the geological conditions into account as much as possible. Great, but not excessive, amounts of grout were utilized.

SEEPAGE UNDER DAMS P

Hammad, H.Y.

American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division, no.SM4, p.25-44, July 1963, Paper 3570.
The two-dimensional problem of steady seepage flow through sand beds under the aprons of dams is examined. The problem is characterized by the provision in the design of (1) a vertical grout curtain under the core of the dam and (2) a vertical row of closely spaced relief walls on the downstream side of the dam. Such conditions were encountered in the design of the High Aswan Dam. Two steps of conformal mapping are used to obtain the complex potential of the flow

pattern. A discharge formula is then obtained for the seepage flux under the dam. The exit gradients needed for the design of the downstream filters to be placed on the exit side are derived. The solution of the simpler problem, for which neither grout curtain nor relief wells exist, is based on the general solution as a limiting case, when the relief wells approach infinity. As a numerical application of the theory, the actual case of the High Aswan Dam is completely developed. The efficiency of the grout curtain in reducing the exit gradients is studied numerically.

A COFFER DAM OR CAISSON WITHOUT TIMBER OR IRON IN ITS CONSTRUCTION P

Harris, R.L.

American Society of Civil Engineers, Transactions, vol.24, no.3, p.230-245, 1891.
During the replacement of the iron bridge crossing Croton Lake with a heavier structure, holes were drilled through the masonry bases at various points in order to fill the voids with grout.

GUNITE BLANKET IMPROVES FOUNDATION GROUTING FOR EARTH DAMS P

Hays, J.B., and Schmidt, L.A.

Civil Engineering, vol.23, p.58-59, April 1953.
Gunite blanket provides better bond than natural rock when grouting Kennedy Dam, British Columbia.

UNUSUAL CUTOFF PROBLEMS - DAMS OF THE TVA P

Hays, J.B., and Schmidt, L.A.

American Society of Civil Engineers, Transactions, vol.110, p.947-1018, 1945.
Grouting in clay in Kentucky dam; Hales Bar Dam foundation leakages stopped by cement and asphalt grout injections without interruption of hydroelectric power operations; a symposium of discussions.

THE PROBLEM OF GROUTING IN DAM CONSTRUCTION P

Heitfeld, K.H.

Denver, Colo., U.S. Bureau of Reclamation, Translation no.729, 1967. (Translation from the German, Die Wasserwirtschaft, vol.56, no.11, p.366-369, 1966.)

When grouting the basement rock, an adaptation of the drilling direction and the composition of the grouting mixture to the textural and structural features of the rock is necessary. Conditions are explained with examples of the Henne, Serpe, and Bigge Dams.

CUT-OFFS IN DEEP DEPOSITS OF PERVIOUS MATERIALS AND THEIR EFFECTIVENESS P

Heldt, A., and Persson, T.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.421-440.

At two dams, Gardiken and Asne, the injection of pervious natural strata has mainly been necessitated by demand of protection against subsurface erosion. A grout curtain was constructed at Gardiken. Asne was also grouted. Observation has shown that the desired result has been achieved. At Asne bentonite-cement and deflocculated-bentonite were used. At Gardiken cement-bentonite, and silica-aluminate were used.

FONDATIONS PROFONDES DE L'ENSEMBLE USINE-ECLUSE DE L'AMENAGEMENT DE PIERRE-BENITE SUR LE RHONE-LA MISE HORS D'EAU DU CHANTIER (THE DEEP FOUNDATIONS AND DEWATERING OPERATION FOR THE PIERRE-BENITE POWER DEVELOPMENT AND LOCK ON THE RHONE RIVER) P

Henry, M., and Paubel, R.

International Conference on Soil Mechanics and Foundation Engineering, 6th, Montreal, 1965, Proceedings, vol.2, p.252-256.

Informative case history of the construction of a watertight concrete grout curtain around the perimeter of the excavation for the power plant and lock on the Rhone River. Describes investigations which led to the design and construction. In French, with English summary.

FOUNDATION GROUTING AND JOINT PERMEABILITY MEASUREMENTS AT BENDORA DAM P

Hill, J.K.

Water Power, vol.18, no.11, p.441-445, November 1966; no.12, p.489-494, 498, December 1966; vol.19, no.1, p.21-24, January 1967.

Describes methods used in foundation grouting at Bendora Dam, Cotter River, Australia, and places on record an analysis of grout consumption in hard, fractured metamorphic rocks at the site. Relationships found between joint permeability measurements, made in exploratory drill holes, and grout consumption are discussed. Techniques used to make a joint permeability assessment of the foundations are described and the need to calibrate injection packers when high flow rates occur is emphasized.

STABILIZING HIGHLY STRATIFIED ROCK IN THE RIGHT ABUTMENT OF TWEERIVIEREN DAM P

Hobbs, L.D., and others

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.647-667.
Includes blanket and consolidation grouting, curtain grouting, and contact grouting. So far as determined a homogeneous foundation was created.

GROUTING DONE WITH AIR SEALS LEAKY DAM

Hoffman, A.M.

Compressed Air Magazine, vol.31, p.1841-1842, December 1926.

CHEMICAL GROUTING AT SONGA DAM II C

Holestol, K.

Oslo, Norwegian Geotechnical Institute, Publication no.80, p.29-32, 1968.
The article describes the grouting of the foundation of Songa Dam II, which was carried out from a supply tunnel below the dam. The purpose of this job was to create a watertight curtain in a fissured rock and permeable deposit upon which a part of the dam core was founded. Initially, a total of 18,700 kg of cement was pumped into the foundation without obtaining satisfactory results. This was followed by grouting with a chemical mixture based on ligno-sulfonates. A total of approximately 40,000 litres of the chemical mixture was pumped into the foundation before the job could be successfully completed.

IDIKKI PROJECT FINALLY BEGINS IMPOUNDING WATER P

Engineering News-Record, vol.192, no.7, p.26-27, February 14, 1974.
The Idikki Hydroelectric Complex in India's Kerala State is a textbook study in dam design and construction. There are three major dams under construction that range from a modern, thin concrete arch structure to a classic, old-fashioned masonry rubble dam. The contrasts in technology being applied side by side on the project are remarkable. While aerial cableways deliver concrete buckets to the 555-foot-high Idikki arch dam, workers on the 328-foot-high Kulamavu masonry dam lift 80- to 100-pound chunks of granite onto the head of another worker who carries it to the masons building the dam. The Idikki Dam includes an elaborate program of both curtain and contact grouting. At the Idikki arch site, 37,825 feet of drill holes were required for contact grouting

in the charnokite foundation rock. Curtain grouting called for nearly 10,000 feet of drilling, plus 19,140 feet for drain holes. Similar work on the foundations of Cheruthoni and Kulumavu entails another 100,000 feet of drill holes.

GEOLOGIC STUDIES AT ARBUCKLE DAM, MURRAY COUNTY, OKLAHOMA

Jackson, J.L.

Bulletin of the Association of Engineering Geologists, vol.5, no.2, p.79-99, Fall 1968.
Preconstruction geological investigations indicated that the foundation of the Arbuckle Dam in Oklahoma was competent and essentially watertight. The designer's distrust of the geologists' interpretation resulted in a significant overestimate of the grouting requirement and a substantially higher grouting cost than would have been required.

GROUTING CURTAIN ON THE RUZIN DAM (VYSTAVBA INJEKCNEJ CLONY NA VODNOM DIELE RUZIN) P

Jansta, F.

Vodni Hospodarstvi (Prague), vol.21, no.3, Series A, p.73-77, 1971.
Data on the devices and materials used and the results which were achieved in constructing the grouting curtain for a rock-fill dam whose foundation rock consists of a weakly tectonically disturbed granite. The grout was a mixture of cement and fly ash and was injected from a grouting gallery linking up with the clay core. A detailed description of the grouting procedure is given.

CUT-OFF FOR THE EARTH DAM IN THE RIVER AND ON THE RIGHT BANK AT UKAI C, P

Jathal, M.N., and others

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, Q.32, R.69, p.1089-1113.
The region of highly fractured stringers underlying the alluvium is proposed to be grouted with clay-cement-, clay-chemical-, and chemical grouts. In portions of the cutoff trench where bedrock is not fractured, clay-cement grout will be used.

HILLS CREEK DAM SEEPAGE CORRECTION P

Jenkins, J.D., and Bankofier, D.E.

Specialty Conference on Performance of Earth and Earth-Supported

Structures, Purdue University, Lafayette, Ind., June 11-14, 1972, Proceedings, vol.1, part 1, p.723-733. New York, American Society of Civil Engineers, 1972.

Hills Creek Dam near Eugene, Ore. is a gravel embankment with a central core. When the reservoir was first filled in 1962, minor seepage developed on the downstream slope near the left abutment but decreased over the next few years. In 1970 the seepage increased. The embankment core in the seepage area was grouted with portland cement grout, resulting in a 95% reduction in seepage.

GROUTING FOUNDATIONS FOR GRAVITY-SECTION DAM

Johnson, H.S.

Engineering Record, p.650, December 12, 1914.

Holes 40 ft deep and 10 ft apart drilled and grouted in soft shale overlying sandstone quartzite. Horse Shoe Falls Plant, Alberta.

DEEP CUT-OFFS IN PERVIOUS ALLUVIUM, COMBINING SLURRY TRENCHES AND GROUTING — C, P

Jones, J.C.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.509-524,

Use of a cutoff trench by open cut is not always possible or economical in deep alluviums. When dewatering is difficult or if the depth of the alluviums is excessive (greater than about 50 feet) the cutoff for dams of moderate height may be economically accomplished by use of a slurry trench combined with a grouted cutoff in the deeper portions. The practical limit for a slurry trench is between 80 and 100 ft and is controlled by the construction equipment utilized. In the deeper zones, the cutoff may be extended by grouting. The cost of the grouted portion of the cutoff will be from 4 to 5 times as costly as the slurry trench per square foot of cutoff and may be even more expensive if chemical grouting is required. A description of the design consideration and construction procedures for a slurry trench combined with grouting for a cutoff in deep alluvium is given in the paper.

IMPROVING ARCH ACTION IN ARCH DAMS — P

Jorgensen, L.R.

American Society of Civil Engineers, Transactions, vol.83, p.316-336, 1919-1920, Paper 1431.

Pressure grouting of spaces between adjacent walls of contraction

joints along arch. Should be done at end of cold season after completion of dam with reservoir as empty as possible. Grouting puts initial compression into arch whereby shearing and cantilever stresses can be reduced.

METHOD OF PRESSURE GROUTING OF CONTRACTION JOINTS OF ARCH DAMS P

Jorgensen, L.R.

Engineering and Contracting, vol.50, no.2, p.36-38, July 10, 1918.
Shorter version of Jorgensen paper which appeared in ASCE Proceedings, vol.50, July 1918.

INVESTIGATION OF THE FLOW DISTRIBUTION IN THE GROUTING SYSTEM AND JOINT WHEN RENDERING DAMS MONOLITHIC P

Karolev, V.M., and Maksimov, K.I.

Hydrotechnical Construction, no.1, p.27-32, January 1968. (Translated from Gidrotekhnicheskoe Stroitel'stvo, no.1, p.17-21, January 1968.)
A 20:0.4 water cement grout is used for rendering dams monolithic. This paper studies the flow and pressure distribution during the grouting of joints, employing the method of electric hydrodynamic analogies. This method allows the determination of the main flow conditions in the joint and grouting system, at the same time facilitating the study of the joint grouting process.

EMERGENCY GROUTING OF OLD RIVER LOW SILL STRUCTURE, LOUISIANA P

Kemp, E.B.

Foundations for Dams, An Engineering Foundation Conference, Pacific Grove, California, March 17-21, 1974, p.371-399. New York, American Society of Civil Engineers, 1974.
Emergency grouting operations at the low sill structure along the Old River has accomplished the following: (1) defined the size of the original cavity and filled this cavity with suitable grout; (2) given immediate lateral support to the steel batter and support piles; (3) effectively sealed off the zone beneath the structure; and (4) defined the potential efficiency of the drainage system in the stilling basin.

SELSET RESERVOIR: DESIGN AND CONSTRUCTION P

Kennard, J., and Kennard, M.F.

Institution of Civil Engineers, Proceedings, vol.21, p.277-304, 1962.
Grouting cut-off trench with portland cement.

INTRUSION GROUTING SEALS POROUS CORAL ROCK FOR VEDADO COFFERDAM P

King, J.C., and Anderson, J.R.

Civil Engineering, vol.23, p.454-457, July 1953.
Effectiveness of grouting procedures in sealing highly permeable foundation; dry cofferdam produced for Almendares River Tunnel.

GENERAL PROCEDURE IN INVESTIGATION, DESIGN AND CONTROL DURING CONSTRUCTION OF EARTH- ROCK-FILL DAMS IN NORWAY P

Kjaernsli, B.

Oslo, Norwegian Geotechnical Institute, Publication no.80, p.1-20, 1968.
The rock foundation directly under the core is normally pressure grouted. In general, the drilling and grouting are carried out along three rows parallel to the center line of the core. In the two outer rows the drill holes are primarily shallow holes that extend to a depth of approximately six meters. These holes are generally grouted without making any water-pressure tests. As a second step deeper holes along the centerline are carried down to at least one third of the height of the dam at that location or to a minimum depth of 10 meters. The holes are subjected to water-pressure tests and shall be carried down to a depth where the tests indicate impervious rock. As a rule, the holes are stage grouted starting at the bottom. The grouting mix generally consists of cement, bentonite, and water. The grouting pressure varies with the depth of the packer. The result of the grouting is controlled by extra holes in which water-pressure tests are carried out. Control holes are situated in between holes which have shown untolerable leakage by prior testing.

LEAKAGE THROUGH HORIZONTAL CRACKS IN THE CORE OF HYTTEJUVET DAM P

Kjaernsli, B., and Torblaa, I.

Oslo, Norwegian Geotechnical Institute, Publication no.80, p.39-47, 1968.
Gives a description of the Hyttejuvet Dam and an account of the unforseen high leakage which occurred during the first filling of the reservoir. The grouting operation which reduced the leakage is described. Grouting tests had shown conclusively that grout did not penetrate into the gravel zone and, therefore, grouting of the core would necessarily fill the open cracks and compress the core and thereby close adjacent cracks. The grout holes were drilled to bedrock or to a maximum depth of 30 meters. Stage grouting was employed starting at the bottom of the hole. The primary holes were placed in one row with a spacing of fifty meters and secondary holes in between in the same

row. To assure that the grout did not penetrate into the gravel three additional holes were drilled in the downstream filter. The take of grout in these holes was however, negligible. The grout consumption in the core amounted to 67 tons of portland cement, 33.5 tons of bentonite, 208 tons of sand and 535 tons of water.

NEW WATERPROOFING TECHNIQUE FOR NORWEGIAN DAM M

Kjaernsli, B., and Sande, A.

Oslo, Norwegian Geotechnical Institute, Publication no.98, 1973; also in Shell Bitumen Review, no.37, p.6-7, January 1972.
A trial dam in Norway has been built by an entirely new, simple technique which requires hardly any equipment. Full grouting with bitumen of all the voids in the granular core must be ensured and sufficient attention must be paid to the grading and compaction of the adjacent filter layers.

GROUTING AND DRAINAGE ARRANGEMENTS ON JAMNI DAM SPILLWAY

Klanna, M.M.L.

Indian Journal of Power and River Valley Development, vol.21, no.2, p.48-52, 68, February 1971.

MEASURES SAFEGUARDING THE STABILITY OF THE LISTER DAM, WHICH BECAME NECESSARY BY THE FLOODING AT THE DOWN-STREAM FACE P

Koenig, H.W., and Walter, E.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.715-726.
Cement grouting was performed on part of the toe and the rock to a maximum depth of 30 m prior to execution of drainage borings.

PERMEABILITY AND GROUTING OF ROCK FOUNDATIONS OF DAMS

Koenig, H.W., and Heitfeld, K.H.

International Congress on Large Dams, 8th, Edinburgh, 1964, Transactions, vol.5, p.581-597.
Discusses grout injections to the various rock zones and sealing measures at Sorpe Dam. The measures put into effect were adapted as far as possible to the conditions encountered in the different subsoil zones.

CONSTRUCTION OF VELKA DOMANSA WATER SCHEME

Kovacik, L., Balik, J., and Caras, M.

Vodni Hospodarstvi, (Prague) vol.21, no.1, Series A, p.8-15, 1971.
Describes a 30m-high earth dam which has been constructed of gravel with an inclined clay core which links up with the grouting gallery. Gives requirements for grouting, used grouting pressure, and composition of grouting mixtures.

DEEP CUT-OFF TRENCH OF PUDDLED CLAY FOR EARTH DAM AND LEVEE PROTECTION M

Kramer, H.

Engineering News-Record, vol.136, no.36, p.76-80, June 27, 1946.
Tests by Army Engineers demonstrates effectiveness of a new method of preventing both through-seepage and under-seepage in earth levees and dams. Sealed a deep cutoff trench with clay slurry and backfilled with puddled clay.

THE ORIENTATION OF GROUT CURTAINS ACCORDING TO THE SYSTEMS OF DISCONTINUITIES IN THE BEDROCK M

Kreuzer, H., and Schneider, T.R.

International Society for Rock Mechanics Congress, 2nd, Belgrade, 1970, Proceedings, vol.3, Theme 6, no.1, p.129-135.
Geomechanical properties of the foundation rock determine the position and structure of the grout curtain of dams. A careful survey of the natural and excavation surfaces determines the geologic structure.

THE EFFICIENCY OF THE GROUT CURTAIN OF DURLASSBODEN DAM (AUSTRIA) AND THE CONSTRUCTION OF A DEEP CUTOFF WALL FOR THE EBERLASTE EARTHFILL DAM OF THE ZEMM HYDROELECTRIC SCHEME

Kropatschek, H., and Rienossl, K.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.247-275.
In both dams, sealing could not be extended as far as the bedrock. The report discusses the observations made during the first filling of Durlassboden Reservoir. The measured data showed that the grout curtain, having a maximum depth of 65m fully met the requirements.

TRAVAUX D'ETANCHEMENT DU-SOUS-SOL DU BARRAGE DE DURLASSBODEN P, M
(GROUTING OF THE SUBSOIL OF THE DURLASSBODEN DAM)

Kropatschek, H., and Rienossl, K.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.695-713.
The subsoil was made impervious by placement of a grout curtain. Grouts used were clay cement gel, bentonite gel, and algonite gel.

DESIGN AND CONSTRUCTION OF A DEEP CUTOFF P

Lacroix, Y.H.

Doctoral Dissertation, University of Illinois, 1961, 584p.
Details of grout curtain of unprecedented size and a sheet pile cutoff installed in the dam core to withstand very large differential settlements at Mission Dam in British Columbia, Canada.

ROZKOS DAM AT CESKA SKALICE

Lampa, L.

Vodni Hospodarstvi (Prague), vol.19, no.2, Series A, p.37-43, 1969.
A grout curtain goes down from the grouting gallery as low as 45 meters below the base of the core under Rozkos Dam.

FOUNDATION TREATMENT AT THE MUDA RIVER SCHEME, MALAYSIA P

Lancaster-Jones, P.F.F.

Civil Engineering & Public Works Review, vol.64, no.761, p.1209-1210, December 1969.
Deals with 2 dams: Muda Dam and Pedu Dam on quartzites with interbedded mudstones dipping 15-20 degrees with strata almost parallel to the surface on the right bank. Also, a major shear zone occurred in river bed almost parallel to the stream, and minor faulting and flooding were evident. At Pedu the strata were almost vertical and parallel with the dam axis. Main foundations were on quartzite with mudstones and conglomerates. Curtain grouting performed at both dams and cavity grouting performed behind the lining of the Saiong Tunnel which was driven through siltstones of thin sandstone. Muda curtain grouting followed the cutoff trench at the upstream toe of the dam.

SOME ASPECTS OF DAM CEMENTATION PRACTICE P

Lancaster-Jones, P.F.F.

Water Power, vol.16, no.5, p.226-231, May 1964.
The author surveys modern procedures in grouting, including both rock strata and alluvial deposits for dam foundations.

WANAPUM DEVELOPMENT -- SLURRY TRENCH AND GROUTED CUT-OFF

La Russo, R.S.

Grouts and Drilling Muds in Engineering Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, May 1963, ed. by A.D.M. Penman, p.196-201. London, Butterworths, 1963.
This paper presents a description of the foundation conditions at the Wanapum Dam (Washington), a summary of the field and laboratory testing of the slurry trench and alluvial grouting methods, and the details of design and construction procedures which evolved from these tests and were used in the building of the underground cutoffs.

SEALING PERMEABLE FOUNDATIONS OF DAM WITH GROUT

Lea, W.S.

Engineering and Contracting, vol.60, p.548, September 12, 1923.

DIFFERENT SYSTEM OF GROUTING IN DEEP UNCONSOLIDATED SEDIMENTS

Lenahan, Tom

Water Power and Dam Construction, vol.27, no.12, p.441-442, 12 December 1975.
Describes an unusual technique for grouting which could provide an effective means of stopping leakage under earthfilled dams. The selective placement of grout in the sediments to act as a binder and to solidify the sediments to prevent water leakage is the objective of the grouting operation.

PREVENTION OF SEEPAGE AND PIPING UNDER DAMS BUILT ON PERMAFROST AND RELATED PROBLEMS CONNECTED WITH THE DESIGN AND CONSTRUCTION OF SUCH DAMS M

Lewin, J.D.

International Congress on Large Dams, 3rd, Stockholm, June 1948, Transactions, vol.2, Question 10, R66.
Recommends grouting with asphalt as bituminous materials in permafrost areas.

FOUNDATION EXPERIENCES, TENNESSEE VALLEY AUTHORITY P

Lewis, J.S.

American Society of Civil Engineers, Transactions, vol.106, p.685-848, 1941.
Symposium of papers on Norris, Gunterville, and Chickamauga Dams. Grouting to reduce uplift and consolidate rock, grouting to form curtain under structures, and grouting on reservoir rims.

GROUT CURTAIN TO CUT THE UNDERGROUND LEAKAGES OF SFUNDAU LAKE IN ORDER TO INCREASE THE RESERVOIR P

Liechti, W., and Wullimann, E.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.39-99.
Execution of classical grout curtain from an exploratory and grouting tunnel in the spillway area. Work was done in three stages--geological prospecting, principal grouting and complementary grouting.

THE USE OF TROPICALLY-WEATHERED SOILS IN CONSTRUCTION OF EARTH DAMS P

Little, A.L.

Asian Regional Conference on Soil Mechanics and Foundation Engineering, Third, Haifa, September 25-28, 1967, Proceedings, vol.1, p.35-41.
This paper describes methods of design and particular problems encountered at four dam sites. Pore pressures during construction of the Hong Kong dams were low and presented no particular difficulties. At the Shek Pik damsite serious cracking developed in the core and had to be corrected by an extensive grouting program.

RECENT DEVELOPMENTS IN THE DESIGN AND CONSTRUCTION OF DAMS AND RESERVOIRS ON DEEP ALLUVIUM, KARSTIC AND OTHER UNFAVORABLE FORMATIONS

Londe, P.

International Congress on Large Dams, 10th, Montreal, 1-5 June 1970, Transactions, vol.5, Question 37, p.143-221.
Contains several brief sections on grouting of dams (p.158, 160, 177, 178, 203, 208, 209, 212).

STABILITE DES MASSIFS ROCHEUX APPLICATION AUX BARRAGES (APPLICATION OF ROCK MASS STABILITY CONCEPT TO DAMS) P

Londe, P.

Annales de l'Institut Technique du Batiment et des Travaux Publics, vol.21, no.251, series 69, p.1615-1637, November 1968.
Several examples are given to show how the physical conditions governing the stability of a dam abutment can be estimated or how safety can be improved by suitable grouting and drainage treatment. In French with brief English summary.

THE GROUT CURTAIN OF SYLVENSTEIN DAM P, M

Lorenz, W.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.19-36.
100 m deep grout curtain for 41 m dam in Bavarian Alps. The grout was a clay-base thixotropic suspension with small additions of portland cement and sodium silicate. The pressure grouting method was used. Results of check measurements given. A measuring method is introduced that is suited to show up any changes in the permeability of the sealing curtain.

THE GROUT CURTAIN OF SYLVENSTEIN DAM (GERMANY); METHODS OF OBSERVATION AND MEASUREMENT

Lorenz, W., and List, F.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.3, p.317-327.
The measuring techniques to date are discussed, mention being made of the difficulties encountered. Mode of operation and details of the new measuring procedure are described that uses compressed air to indicate water levels.

CUT-OFFS IN NATURAL RIVER BANKS IN CONNECTION WITH THE CONSTRUCTION OF OSSAUSKOSKI POWER PLANT AND KEMI LAKE REGULATION RESERVOIR P

Lounamaa, M.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.379-395.
A pervious moraine layer was sealed by grouting a 30 m long cut-off curtain with cement grout, cement-bentonite grout, and deflocculated bentonite grout. Regular portland cement was used.

CONSTRUCTION OF ENCUMBENE DAM P

Mackintosh, T.A., and Moore, P.J.

Journal of Institution of Engineers, Australia, vol.33, no.3, p.59-74, March 1961.
Discusses foundation grouting and applications of 50-ft-deep grout curtain during construction of earth dam.

DIE AUSFUHRUNG UND WIRKSAMKEIT DER UNTERGRUNDDICHTUNG BEI DEN STAUDAMMEN DER DRAUKRAFTWERKE EDLING UND FEISTRITZ (METHOD AND EFFECTIVENESS OF SEALING THE SUBSOIL OF THE DAMS OF THE *DRAU POWER STATION AT EDLING AND FEISTRITZ*) P

Magnet, E., and Mussnig, R.

Talsperren Oterreichs-Schriffenreiche (Vienna), no.18, p.70-92, 1970.
The sealing of the pervious soil layers under the side dams for the reservoirs of the Drau Power Station is discussed. Walls were sealed by injecting under pressure a watertight mixture of cement, bentonite, blown ash, and sand.

REALISATION PAR INJECTION D'UN ECRAN IMPERMEABLE EN MATERIAU ALLUVIONNAIRE (THE CONSTRUCTION OF A GROUTED IMPERVIOUS SCREEN COMPOSED OF ALLUVIAL MATERIALS) C, P

Maigre, R.

International Congress on Large Dams, 5th, Paris, 1955, Transactions, vol.1, p.757-801.
At the site of a 120m high earth and compacted alluvial dam in France, extensive field tests were conducted to determine if a vertical screen could be installed to a depth of 110m in very permeable gravel saturated with aggressive thermal water. Field grouting tests showed that the permeability could be reduced up to a satisfactory level and gave information which made it possible to reduce the quantities of grouting materials and to verify the quality of the grouting in a large rock mass. In French with English summary.

DUAL GROUTS SEAL FOUNDATION UNDER DAM C, P

Mann, Warren

Construction Methods and Equipment, vol.52, no.8, p.42-44, August 1970.
To insure against any seepage through foundation and abutments for rockfill dam with an impervious clay core on the Keewee River in

Oconee County, South Carolina, the contractor is using a chemical grout as a backup curtain to cement grout. A pattern of cement grouting holes is determined according to the apparent seams and joint planes in the rock. The cement curtain is ten feet wide, with a series of upstream and downstream holes staggered on ten-foot centers. Between these two lines, the contractor drills another series of staggered holes. In these, they pump American Cyanamid AM-9 chemical grout to form a safety curtain in the center of the cement. The chemical actually seals the finer cracks in the rock that the cement will not penetrate. While being pumped into the seams, it has the same viscosity as water and therefore will flow into the same areas as water. It sets up like a hard jello, but it only has a strength of fifty psi. The cement on each side of the chemical binds it, providing an impervious consolidation of the dam foundation and abutments. This dam is located on the Keowee River in Oconee County, South Carolina.

THE END OF A DAM FOUNDED ON ALLUVIUM: THE LEFT BANK WING OF THE MONT CENIS DAM — P

Marchand, R., Daveau, J.C., and Sabarly, F.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.47-68.
Describes problems of stability of the foundation, measures used to study the composition, geology and hydrogeology of the bank, the data collected, and suggestions for treatment, control and possible drainage at the time of impoundment.

EFFECTIVENESS OF CUTOFFS IN EARTH FOUNDATIONS AND ABUTMENTS OF DAMS — P

Marsal, R.J., and Resendiz, Daniel

Pan American Conference on Soil Mechanics and Foundation Engineering, 4th, San Juan, Puerto Rico, June 1971, Proceedings, vol.2, p.257-273. New York, American Society of Civil Engineers, 1971.
Three types of cut-off used in three Brazilian earth dams founded on the same geologic formation. The first one at Limiro Dam is a positive cut-off. In the Euclidos da Cunha Dam cut-off the concrete wall was supplemented by a drainage and grouting gallery. In the Graminha Dam grouting was omitted. It was concluded that the good control of piezometric water level obtained in these dams is due to the drainage disposition and not to the grouting.

LA LUTTE CONTRE LES EROSIONS SOUTERRAINES AU BARRAGE DU GHRIB (THE FIGHT AGAINST SUBTERRANEAN EROSION AT THE GHRIB DAM) P

Martin, M.

Congress on Large Dams, 2nd, Washington, 1936, Transactions, vol.4, p.50-66.

THE MATTMARK DEVELOPMENT C, P, M

Water Power, vol.18, no.3, p.95-102, March 1966; no.4, p.147-150, April 1966; no.5, p.189-195, May 1966.
In Switzerland's Mattmark Dam cut-off grout curtain below dam was used to seal the foundation to bedrock. Materials used were clay, cement, bentonite, silicate and other chemicals, and clay-cement.

QUELQUES REFLEXIONS SUR L'UTILISATION DES INJECTIONS DANS LES BARRAGES P

Mayer, A.

Geotechnique, vol.11, no.4, p.328-332, December 1961.
Use of grouting in dams. Discusses grouting techniques for improving impermeability of cracks, reduction of negative pressures and consolidation of foundations. In French.

ENGINEERING GEOLOGY OF SPRUCE RUN DAM AND RESERVOIR, NEW JERSEY P

McGavock, C.B., and Depman, A.J.

Geological Society of America, Engineering Geology Case Histories, no.6, p.23-32, 1968.
Informative case history discusses the engineering geology of the area and its effect on design and construction. Discusses grouting methods, materials, and drilling and grouting equipment.

METHOD OF SOLIDIFYING CHAMBERED AND POWDERED ROCK FOR EXCAVATION FOR POWERHOUSE AND DAM FOUNDATION

Engineering and Contracting, p.89, January 24, 1912.

IMPERMEABILIZACION DE UN ALUVION DE GRANULOMMETRIA FINA P
(GROUTING OF A FINE GRANULAR ALLUVIUM)

Micucci, D.A.I., Scolaro, H., Bolognesi, A.J.L., Moretto, O.

Pan American Conference on Soil Mechanics and Foundation Engineering, 3rd, Venezuela, 1967, Proceedings, vol.2, p.121-141.
Construction of a grout curtain with a clay-cement grout using clay from a nearby borrow pit. Describes the soil to be grouted, the grouts used and the injection methods and results of two full-scale grouting tests. In Spanish with English summary.

SEALING UP GROUNDWORK BEDDING OF DAMS BUILT ON CARPATHIAN FLYSCH P

Mikucki, Z.

Soil Mechanics and Foundation Engineering, Second Seminar, Lodz, September 1970, Proceedings, p.701-715.
Description of geological conditions and details of grouting procedure for four dams whose foundations were sealed by cement injections. Recommendations on blasting procedure, treatment of the rock surface, and injection procedures.

IMPERMEABILIZACION DEL MACIZO KARSTICO DE CANALLES (SPAIN)
(WATERPROOFING OF THE KARSTIC MASSIF AT CANALLES (SPAIN))

Millet, G., and Alvarez, A.

Revista de Obras Publicas, vol.120, no.3098, p.423-436, 1973.
The location of the Canalles Dam in a canyon formed by the river in massif limestone presented important waterproofing problems in one abutment. Radioactive tracers were used to locate the percolation route of the water through and beneath clay layer. After failure of a first cut-off system, a new grouting cut-off was built upstream from the previous one.

DETERMINATION OF NATURAL POSSIBILITIES AND PROVIDING OF P, M
IMPERMEABILITY OF THE RAMA STORAGE, CONSTRUCTED IN KARST REGION

Miodrag, P., Srdic, R., and Bubalo, K.

International Congress on Large Dams, 10th, Montreal, 1-5 June 1970, Transactions, vol.2, p.899-915.
The erection of the storage reservoir for Hydro Power Plant Rama was performed in a karst valley. The results of testing were shown to

determine the impermeability of a storage edge section. It was established that the only possibility of water leakage is through the dam abundments. Therefore, a grouting curtain was performed with the surface of 86,500 m^2, and some 37,500 m of boreholes were bored out in total. A three-component grouting mixture was applied: Cement-clay-bentonite.

CLAY GROUTING WORK AT UKAI DAM (GUJARAT STATE) C, P

Mistry, J.F.

Indian National Society of Soil Mechanics and Foundation Engineering, Journal, vol.4, no.3, p.313-322, July 1965.
Laboratory experiments have been conducted on the effect of different deflocculating agents on the properties of clay-bentonite-cement grouts. The effect of the order in which the ingredients are mixed has also been investigated. The costs for the different types of grouts have been worked out and the economy in using clay grouts is pointed out.

SUBSURFACE EXAMINATION OF FOUNDATION OF EARTHEN DAM ACROSS TAPI RIVER AT UKAI

Mistry, J.F., and Kulkarni, V.N.

Journal of the Institution of Engineers (India), Civil Engineering Division, vol.51, no.1, part C1, p.41-46, 1 September 1970.

MIXING MACHINE SPEEDS FOLSOM DAM GROUTING P

Engineering News-Record, vol.154, p.45, January 20, 1955.
Description of Colcrete mixer as modified by Corps of Engineers to mix neat cement grout.

STORAGE DAM ON THE RIVER STRELA NEAR ZLUTICE

Mlynek, J., Jires, J., and Hulanova, V.

Vodni Hospodarstvi (Prague), vol.6, no.6, p.153-160, 1969.
Description of the rock-fill dam and the structures belonging to it. The rockfill is from mica-schist gneiss with a sloping clay core which links up with the grout gallery. Contains data on grout curtain installation.

EVALUATION DE L'ABSORPTION DE CIMENT DES VOILES D'ETANCHEITE DANS LES MASSIFS ROCHEUX (DETERMINATION OF CEMENT CONSUMPTION IN GROUTED CURTAINS) P

Molina, P.S.

International Symposium on Rock Mechanics, Madrid, 1968, Proceedings, p.401-407. Madrid, Editorial Blume, 1970.

Attempt made to determine in advance the average consumption of cement in the curtain. Method based on statistical analysis of the spacings between holes and between lines of holes foreseen for the curtain. Method may be applied in determining the most suitable spacings between the elements of the grout curtain.

MORROW POINT DAM IS BU REC FIRST P

Engineering News-Record, vol.173, no.6, p.95-96, August 6, 1964.

The dam contains some 360,000 cu yd of concrete. It is divided into 40-ft-wide blocks by vertical radial contraction joints to confine shrinkage openings to predetermined planes. The joints are keyed and grouted to assure watertightness and monolithic action of the dam. After the concrete cooled to 40 degrees Farenheit, workmen grouted the contraction joints and then filled the cooling pipes with grout.

A REVIEW OF THE INFLUENCE OF GEOLOGY ON THE DESIGN AND CONSTRUCTION OF IMPOUNDING DAMS M

Morton, Edgar

Journal of the Institution of Water Engineers, vol.27, no.5, p.243-271, July 1973.

This paper reviews the changes in the design and construction of impounding dams. It has become common to sink boreholes to relieve pressure and control seepage under concrete and earth dams. Substantial changes have taken place in grouting techniques to limit seepage around the abutments of dams.

EFFICIENT DEVICE USED IN GROUTING LOCK FOUNDATIONS

Muntz, E.P.

Engineering and Contracting, p.179, February 23, 1916.

CONSTRUCTION AND BEHAVIOUR OF THE GROUT CURTAIN IN THE ALLUVIAL FOUNDATIONS OF GIRNA (INDIA) EARTH DAM C, P

Murti, N.G.K., Saldanna, E.C., and Sakhalkar, S.C.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.1075-1100.
Account of the performance of the grout curtain formed by clay-cement-bentonite and chemical grouting to control the seepage through the foundations. Performance of grout curtain was judged by observing piezometric heads in the foundation upstream and downstream of the curtain, through stand-pipes installed at five different cross-sections.

MAKING THE JOINTS IN CONCRETE DAMS MONOLITHIC (KVOPROSU OB OMONOLICHIVANIS BETONNYKH PLOTIN) P

Murzanov, V.A., Ashikhmen, V.A., Sovalov, I,G., and Khayutin, Y.G.

Hydrotechnical Construction, no.10, p.873-877, October 1968. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.10, p.17-19, October 1968.)
The use of grouting systems with linear outlet slots, in conjunction with the application of activated cement grouts and of a special injection technology in concrete dam construction is discussed.

NATIONAL COMMITTEE ON LARGE DAMS OF THE REPUBLIC OF SOUTH AFRICA, GENERAL PAPER NO.10 P

The National Committee on Large Dams (South Africa)

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.4, Part I-4-E, p.852-853.
Discusses grout intrusion concrete.

FOUNDATION TREATMENT FOR UNDERSEEPAGE CONTROL AT TARBELA DAM PROJECT

Nawaz Khan, S., and Ali Naqvi, S.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.1167-1193.
The Tarbela Dam Project in West Pakistan comprises an earth and rockfill main dam. Seepage control features consist of an inclined impervious core, an impervious blanket extending upstream from the toe of the main dam, grout and drainage curtains, drainage blanket, and drainage wells.

THIXOTROPIC GROUT FILLS DRAINAGE CHANNEL IN INSPECTION GALLERY STRUCTURE OF BEVER DAM P

Neumann, H., and Osselmann, C.R.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.3, p.21-30.
A thixotropic grout was used to fill a drainage channel. The grout had to meet high requirements, especially concerning impermeability, water inclusion without bleeding, and rheological characteristics. A cement-bentonite mixture was selected.

NEW IDEAS AT YELLOWTAIL DAM P

Western Construction, vol.37, no.11-A, p.43-48, November 1962.
During construction of an arch dam, grouting tunnels of up to 3,000 ft were driven into the abutment. The grouting material contains a bulking material to cut down the amount of costly cement required. Some of the grouting holes took up to 6,000 sacks of mixture.

DETERIORATION PROBLEMS AT AVON DAM P

Nicol, T.B., and others

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.3, p.713-730.
Regrouting the foundations was brought about by increases in foundation leakage and uplift. A grout curtain was drilled from the lower inspection gallery. The downstream face of the dam was successfully gunited, after erosion of sandstone aggregate had occurred.

WARRAGAMBO DAM P

Nicol, T.B.

Institution of Civil Engineers, Proceedings, vol.27, p.491-546, March 1964, Paper no.6721.
Describes the grouting required in this Australian project including (1) marcusite (iron sulphide), (2) blanket, (3) informed inter-pressure curtain, (4) high pressure and wing curtain, and (5) construction joints.

NO FINES CONCRETE AND PFA FOR NEW PENNINE DAM P

Consulting Engineer, vol.31, no.4, p.65, April 1967.

Rapid hardening cement and pfa (pulverized fuel ash) to be used to grout sandstone and shale strata below the dam to form a cutoff curtain. The rapid hardening properties of the cement are of new significance at the water/cement ratio used in grouting but the fine particle size is of practical use in grouting work.

PERMEABILITY, UPLIFT PRESSURE, SEEPAGE DISCHARGES P

Nonveiller, E.E.

International Symposium on Rock Mechanics, Madrid, 1968, Proceedings, p.369-377.
Discusses problems of grouting and seepage in rock media with special reference to grout curtains at the Aswan Dam. Discusses differences between rock foundations with more or less regular fractures, and fractured rock with faults and solution openings. Case study of Senj Hydroelectric Power Plant in which carstified limestone created difficult grouting operations.

PERUCA ROCKFILL DAM IN YUGOSLAVIA P

Nonveiller, E.E.

Indian Journal Power & River Valley Development, vol.10, no.12, p.89-103, December 1960.
Describes use of grout curtain in fissured rock under 180-ft-high dam, testing of strength and permeability of clay/cement grout mixes, and description of grout pumps.

BEDROCK STABILITY BEHAVIOR WITH TIME AT THE PLACE MAULIN ARCH-GRAVITY DAM P

Oberti, G., and Rebaudi, A.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.849-872.
A cement grout curtain set up at the upstream toe of the dam. The treatment of the rock has been complemented by chemical grouting.

TEST GROUTING FOR OROVILLE DAM P

O'Neill, A.L., and Lyons, M.S.

Engineering Geology, (Bulletin of the Association of Engineering Geologists), vol.1, no.1, p.1-13, January 1964.
Test grouting and grouting program. Neat cement grout was injected in

different colors for different grouting conditions and a drift was later driven through the grouted area in order to observe the in-situ results.

STRUCTURAL GROUTING FOR OROVILLE DAM COREBLOCK

O'Rourke, J.E.

American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, vol.103, no.GT5, p.367-380, May 1977, Paper 12905.
A concrete coreblock, a foundation structure for the core of the Oroville Dam earth-fill embankment was damaged by excessive deformations induced by embankment loads during construction. A core drilling operation and structural grouting program is described.

FOUNDATION PROBLEMS AT BHAKRA DAM AND THEIR TREATMENT P

Palta, B.R., and Aggarwala, S.K.

International Congress on Large Dams, 9th, Istanbul, 4-8 September 1967, Transactions, vol.1, p.1037-1049.
Consolidation (blanket) grouting by pressure grouting of entire foundation area. Intermediate curtain grouting performed from the main foundation gallery with cement. Final curtain grouting was performed with cement. Contacts were grouted.

PREVENTION OF CRACKS IN CONCRETE DURING THE CONSTRUCTION OF BHAKRA DAM

Palta, B.R., Aggarwala, S.K., and Rao, P.S.

International Congress on Large Dams, 10th, Montreal, 1-5 June 1970, Transactions, vol.4, p.599-615.
Contains brief section on contraction joints grouting.

EPOXY GROUTING OF CRACKS IN DAMS; DOES IT REALLY HELP? M

Pande, G.N., and Sharma, V.M.

The Indian Concrete Journal, vol.46, no.4, p.165-166, April 1972.
This paper discusses the utility of repairing cracks in dams by grouting with epoxy.

RECONNAISSANCE, GEOLOGIC ET TRAITEMENT DE LA FONDATION DE BARRAGE DE MAUVOISIN P

Parejas, E., and Rambert, O.

International Congress on Large Dams, 5th, Paris, 1955, Transactions, vol.4, p.1179-1195.
Exploratory and grouting operations at the site of a single arch dam in Switzerland. To seal the rock, a main grout curtain was installed. A secondary grout curtain sealed and consolidated the foundation, especially at the upstream toe of the dam. Consolidation grouting was performed to reinforce the zone of high stresses in the abutments at the downstream toe of the dam. Text in French.

DISORDERS IN A LARGE CHALK EMBANKMENT P

Pasturel, D.

Bulletin de Liaison des Laboratoires Routiers, Laboratoire Central des Ponts et Chaussees, no.36, p.119-134, 1969.
Describes some of the research which is being carried out concerning problems posed by the construction of large chalk embankments. Topics include disorders which have appeared in the form of numerous fissures and investigations to determine its origin, measurements of water content, and verification of deformations by vertical reference tubes.

BENTONITE CEMENT GROUTS (JPP 35-43) C, P

Patch, O.G.

American Concrete Institute, Proceedings, vol.35, p.590, 1939.
A 2% mixture of bentonite and water was added to the calcium chloride and cement to make a grout mix which developed a 28-day strength of about 2,000 lb, saving the contractor $3.00 or more per cubic yard. Another successful use was made of bentonite at the time of a serious leak in the cofferdam. A 2% - 5% solution of bentonite was used to mix with cement to make a grout into which sawdust and other materials were mixed. This was pumped into the water channel. Bentonite resists the erosive action of flowing water and this allowed the cement to set up before it could be washed away.

ENGINEERING GEOLOGY OF THE LEMONTHYME HYDRO-ELECTRIC SCHEME, TASMANIA P

Paterson, S.J.

Institution of Engineers, Australia, Civil Engineering Transactions, vol.CE13, no.1, p.17-24, April 1971.

This paper describes the engineering geology of the hydroelectric development based upon diversion of water from the Mersey and Fisher Rivers to the River Forth in Northwest Tasmania. The diversion dam was built in a glaciated valley upon glacial and associated deposits that are in excess of 200 ft in thickness. A deep cut-off trench was necessary because of the presence of permeable beds and extensive grouting was carried out in the open jointed rock on the left abutment. The power tunnel is mostly unlined in schist and quartzite. A major rock fall occurred in the tunnel after five months service.

CLEANING AND GROUTING LIMESTONE FOUNDATIONS, TENNESSEE VALLEY AUTHORITY — P

Pauls, A.L., and Taylor, T.F.

American Society of Civil Engineers, Transactions, vol.113, p.79-138, 1948.
Treatment of channels and cavities in limestone foundations of Fort Landoun Dam and Douglas Dam.

SUCCESSFUL COMPLETION OF THE PERUCA STORAGE IN THE DINARIC KARST — P

Pavlin, B.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, p.565-592.
Discusses details of grout mixes and grouting methods and of subsequent tests to check the effectiveness of the grout curtain to control seepage through alluvium over dolomite in the dam foundation. In French.

GROUTING WORKS AT THE HEADWATER TUNNEL OF HYDROELECTRIC POWER PLANT RAMA — P

Pavlovic, M.

Congress, International Society for Rock Mechanics, Second, Belgrade, 1970, Proceedings, vol.2, Theme 4, p.427-437.
Stress grouting to prestress the concrete lining and consolidate the rock was based on extensive research including geological investigations, geotechnical research and series of laboratory tests for power plant in Yugoslavia.

GROUTING, DRAINAGE AND HYDRAULIC INSTRUMENTATION OF RAPEL DAM (CHILE) — P

Pena, H., Grado, J., Barbedette, R., and Pautre, A.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.651-680.

System of extensive drainage system of superimposed galleries connected by boreholes and a shallow grout curtain designed to limit percolation to acceptable values was adapted after close geological survey of the excavations and galleries.

CASE RECORDS OF CEMENT GROUTING P

Perrott, W.E., and Lancaster-Jones, P.F.F.

Grouts and Drilling Muds in Engineering Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers held May 1963, ed. by A.D.M. Penman, p.80-84. London, Butterworths, 1963.
Dokam, Errochty, Glendevon, Shirawato Dam grouting.

SEEPAGE AND ANTISEEPAGE MEASURES ON DAMS BUILT UP ON CARPATHIAN FLYSCHES P

Peter, P.

International Congress on Large Dams, 8th, Edinburgh, 1964, Transactions, vol.2, p.493-501.
Discusses seepage and antiseepage measures on some dams in Czechoslovakia. Seepage from the grout curtain height for a given strata may be computed by empirical functions which have been worked out.

MEASURES AND PROCEDURES ADOPTED TO INSURE THE STABILITY AND SAFETY OF FOUNDATIONS FOR THE PONGOLAPOORT DAM P

Phelines, R.F.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.619-646.
Extensive grouting of open joints upstream of and beneath the dam and of the contact between the concrete and the foundation rock is called for in the construction specification.

DESIGN AND CONSTRUCTION OF GEEHI DAM C, P

Pinkerton, I.L., and Paton, R.J.

Institution of Engineers, Australia, Journal, vol.40, no.3, p.33-48, March 1968.
AM-9 used to inject into highly weathered granite. Foundation rock grouted with cement grout to provide both a blanket and a deep cut-off curtain. Cement grouting to fill seams to prevent loss of chemical grout done first.

EARTH OVERFLOW DIKE, JIM WOODRUFF DAM P

Polatty, J.M.

American Society of Civil Engineers, Proceedings Separate no.222, vol.79, July 1953.
Earth dike is rolled fill structure with impervious core; grouted riprap on face; grouting procedure explained.

CONSTRUCTION OF THE GROUT CURTAIN FOR THE DOWNSTREAM COFFERDAM TRENCH AT THE TOKTOGUL'EK HYDROELECTRIC PLANT DAM

Ponimatkin, P.U., and Kheifets, V.B.

Hydrotechnical Construction, no.12, p.1103-1107, December 1969. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.12, p.7-8, December 1969.)

DESIGN OF BOUNDARY ARCH DAM P

Pospisil, J., and Hayes, M.D.

American Society of Civil Engineers, Journal of the Power Division, vol.96, no.PO1, p.73-91, January 1970, Paper 7012.
During construction of this dam, artificial cooling was utilized during the grouting process, by circulating seasonally, cold river water through aluminum tubes. In addition, an artificial cooling plant was installed as insurance against delays that might have required grouting in warm weather.

FOUNDATIONS AND ABUTMENTS -- BENNET AND MICA DAMS P

Pratt, H.K., McMordie, R.C., and Dundas, R.M.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundation Division, vol.98, no.SM10, p.1053-1072, October 1972, Paper 9290.
Two large earthfill dams, one founded on rock, and the other on rock and overburden, illustrate the treatment of foundations and abutments for high earth fill dams in western Canada. Foundation treatment and curtain grouting is discussed.

CONSTRUCTION OF TWO LARGE DAMS IN THE CARPATHIAN FLYSCH OF RUMANIA P

Priscu, R., Bancila, I., Teodorescu, A., and Flegont, G.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.729-754.

Execution of ample grouting and consolidation work carried out by injections of cement suspension were imposed by natural conditions. Dam foundation was treated with linings and concrete stoppings--over which a reinforced concrete socket was molded.

MESURES POUR ASSURER LA STABILITE ET L'TANCHEITE DU VERSANT DROIT DU BARRAGE STRIMTORI (MEASURES TO ENSURE THE STABILITY AND THE WATERTIGHTNESS OF THE RIGHT BANK OF STRIMTORI DAM) P

Priscu, R., Teodorescu, A., and Flegont, G.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.1145-1159.
A grout curtain carried out step by step was placed as a continuation of a 25 m deep diaphragm of concrete built under the rockfill dam.

FOUNDATION TREATMENT OF RIO CASCA III DAM P

Queiroz, L.A., Oliveira, H.G., and Nazario, F.A.S.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.321-333.
Intense jointing of rock in area adjacent to canyon walls dictated grouting. Water tests showed open joints and contact surfaces between sandstone lenses requiring treatment. The effusion of the grout curtain will be assessed by control holes made with rotary drilling equipment. The contact zone of the clay core in the rock abutments will receive a gunite coating to provide smoother surface for compaction of the clay core.

BEHAVIOUR OF GROUTED CUT-OFF ON GLOBOCICA DAM

Radukic, Vladimir

International Congress on Large Dams, 12th, Mexico City, March 29-April 2, 1976, Transactions, vol.2, p.903-935.
The grouted cut-off of Globocica Dam is a wide impervious barrier connecting impervious core to the grout curtain in the bedrock. It has been accomplished in selected granular fill, alluvial deposit and limestone and bedrock by the grouting from the triple-tube grouting gallery. The grouted cut-off was designed during construction in order to save time when the construction of positive cut-off proved to be extremely difficult due to unexpectedly high rate of flow into the foundation pit.

BARRAGE DE "VRTAC" - CONSTRUCTION DES BARRAGES DANS L'EAU ET DANS DES SITUATIONS EXCEPTIONNELLES (CONSTRUCTION OF DAMS UNDER WATER AND IN UNFAVORABLE SITUATIONS) P

Rajcevic, Bogdan

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.4, p.529-539. In French.

FONDATION DU BARRAGE DE VLASINA (FOUNDATION OF THE VLASINA DAM) P

Rajcevic, Bogdan, and Vercon, Milan

International Congress on Large Dams, 5th, Paris, 1955, Transactions, vol.1, p.859-866.
Several advantages of using grouting and supervision galleries in earth dams on highly permeable soil are: (1) Visiting and controlling construction operations, (2) conducting constant groutings, and (3) assuring a good contact between the clay core wall and the grout curtain. In French with brief English summary.

VOILE D'INJECTION DU BARRAGE "VRLA II" (THE GROUTING SCREEN OF THE VRLA II DAM) C, P

Rajcevic, Bogdan, and Vercon, Milan

International Congress on Large Dams, 5th, Paris, 1955, Transactions, vol.1, p.867-881.
A Yugoslavian Dam Project supports the authors' contention that it is quite possible to accurately predict all work necessary for underground grouting provided preliminary studies of geological and soil conditions have been made. A brief description is given of the field tests conducted at the Vrla II Dam Site including details of the cement grout consumption. In French with brief English summary.

FREMANTLE GRAVING DOCK-STEEL DAM CONSTRUCTION FOR NORTH WALL

Ramsbotham, J.F.

American Society of Civil Engineers, Transactions, vol.76, p.1942, 1913; also in Engineering and Contracting (Abstract), p.513, May 1, 1913.
A method is shown for sealing grout pipes into tops of drill holes for grouting fissured rock foundations.

GROUTED CUT-OFF FOR THE ESTACADA DAM P

Rands, H.A.

American Society of Civil Engineers, Transactions, vol.78, p.447-489; discussion p.483-546, 1915.
The conclusion was reached that excessive grouting of hole means a wasting of cement.

THE GROUTED FOUNDATION AT THE LAHONTAN DAM

Rands, H.A.

Engineering News, vol.69, no.23, p.1190, June 5, 1913.
Estimated saving of grouting process over that of excavated and concrete-filled trench by $3300. This amount represents only saving between cost of grouted cut-off and extended cost of excavating and filling with concrete a trench of same depth.

PRESSURE GROUTING FOR BETTER FOUNDATION P

Rao, K.K.

Indian Journal of Power and River Valley Development, vol.14, no.2, p.27-30, 32, February 1964.
Discusses both curtain grouting and blanket or consolidation grouting; includes a discussion of grouting pressures and water cement ratios.

UNUSUAL CUT-OFF PROBLEMS AT SRISAILAM HYDRO-ELECTRIC PROJECT

Rao, R.C.

International Congress on Large Dams, 10th, Montreal, 1-5 June 1970, Transactions, vol.2, p.1047-1074.
This paper deals with the foundation problems and the diaphragm treatment effected below the two cofferdams for making the foundations watertight and to prevent seepage of water from the river into the foundation pit of the main dam.

USE OF PRESTRESSING TECHNIQUE IN CONSTRUCTION OF DAMS

Rao, R.M.

Indian Concrete Journal, vol.38, no.8, p.297-300, 305-308, August 1964.

This article describes the use of the prestressing technique in the construction of concrete dams, and particularly in the raising and strengthening of dams. The general principles of design and the principal items of construction such as the drilling of holes for cables, honing-in the cables, and anchoring, tensioning, and grouting are discussed.

FOUNDATION OF HOLJES DAM P

Reinius, E.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.367-377.
Cement used to grout foundations under the dam. The foundation rock is full of cracks and joints, many of which are filled with early material which can be washed out.

SOME FOUNDATION CONSIDERATIONS AT THE GRAND RAPIDS HYDRO-ELECTRIC PROJECT P

Rettie, J.R., and Patterson, F.W.

Engineering Journal (Canada), vol.46, no.12, p.32-38, EIC-63-HYDEL 5, December 1963.
Grout curtain up to 200 ft deep ensures retention of reservoir water. Selection of one of 12 grout mixes based on pressure test results in each drill hole section. Discusses six alternate solutions.

DESIGN ASPECTS OF STRATHFARRAR AND KILMORACK HYDROELECTRIC SCHEME P

Roberts, C.M., Wilson, E.B., and Wiltshire, J.G.

Institution of Civil Engineers, Proceedings, vol.30, p.449-487, March 1965.
Mechanical and electrical aspects of double curvature arch dams are given, with special reference to grouting of contraction joints.

INFLUENCE ON THE BEHAVIOUR OF AN ARCH DAM OF THE HYDROSTATIC PRESSURE ON THE GROUT CURTAIN AND OF THE STRESSES IN THE GROUND UPSTREAM

Rocha, Manuel, and others

International Congress on Large Dams, 10th, Montreal, 1-5 June 1970, Transactions, vol.4, p.541-558.

This paper presents the results of a research program on two phenomena usually not taken into account in the design of concrete dams: (1) tensile stresses in the foundation rock upstream of the dam, (2) influence on the state of stress in the foundation ground and the dam itself of the dissipation of neutral pressures in the rock mass due to the grout curtain and the vertical drains.

ROCK GROUTING AND CAISSON SINKING FOR THE HALES BAR DAM P

Engineering News, vol.70, no.20, p.949-956, November 13, 1913.
Powerhouse secured by combination of open grouting and grouting under blanketing layer of concrete.

ASPHALT GROUTING USED TO FILL CAVITIES IN LEAKY DAM M

Ross, F.K.

Pacific Builder and Engineer, vol.67, p.96-97, September 1961.
The use of asphalt grouting to stop leaks at Lower Baker Dam near Seattle, Washington is discussed. It was found that twice the pressure of the hydrostatic head was needed to stop leaks. At the conclusion of the asphalt grouting, larger holes were drilled and sealed with cement grouting.

LES INJECTIONS ET LES DRAINAGES DE FONDATION DE BARRAGES EN ROCHES PEU PERMEABLES P

Sabarly, F.

Geotechnique, vol.18, no.2, p.229-249, June 1968.
Some aspects of the grouting and drainage of dam foundations are considered, with particular reference to rocks of low permeability. The relative merits of grout and drainage curtains are given. The effect of pressure on discharge in Lugeon-type water tests is considered. The influence of cement grain sizes on groutability is mentioned. The grouting pressures currently used in America and Europe are discussed. Inevitable movements in arch dams during impounding can completely inhibit the performance of grout curtains if not properly designed. The effects of grouting and drainage on bank abutment stability are compared. Sundry comments on drainage systems are made. In French.

FURTHER OBSERVATIONS ON THE BEHAVIOUR OF THE GROUT CURTAIN IN THE ALLUVIAL FOUNDATION OF THE GIRNA EARTH DAM, INDIA P

Saldanha, E.C., and Sakhalkar, S.C.

Asian Regional Conference, Soil Mechanics and Foundation Engineering, Fourth, Bangkok, July 1971, Proceedings, vol.1, p.447-450.

Further observations on stand-pipe piezometers, hydraulic gradients and drops across the grout curtain show subsequent behavior and effectiveness of earth dam on Girna River in India.

BARRAGE SUR L'OUED NEBAANA PROBLEMES D'ETANCHEITE DE LA RETENUE (DAM ON THE WADE NEBAANA (TUNISIA); PROBLEMS OF RESERVOIR WATERTIGHTNESS) P

Samana, R., Vigler, G., Huynh, P., and Sabarly, F.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.683-707.

Grout curtain for dam in Tunisia successful due to choice of maximum grouting pressures which were carefully adapted to the site after numerous tests. Clay-cement and bentonite-cement grouts were of conventional and mediocre quality. In French.

ENSAYE DEL TUNEL DE LA PLANTA MAZATEPEC (TESTING OF PRESSURE TUNNEL OF MAZATEPEC HYDROELECTRIC POWER PLANT) P

Sanchez, T.R.

Ingenieria (Mexico), vol.32, no.4, p.1-9, October 1962.

Testing of section of tunnel test section was chosen in which geological conditions proved to be worst and in which cement absorptions during grouting were highest; test indicates that there is no danger due to leakage of water during maximum pressure.

THE BORDAL EARTH- AND ROCK-FILL DAM P

Sande, Arne

Oslo, Norwegian Geotechnical Institute, Publication no.80, p.21-28, 1968.

Describes the design, the construction and the performance of the Bordala Dam I. This dam is built with a central core of moranic material, and with a supporting fill of gravel. At Bordal I the pore pressure and the temperature in the fill, the settlements along the crest and the leakage through the dam are measured. The results of these measurements are presented in this paper. The grouting was executed with a cement grout mixed to a water cement ratio in weight varying from 5:1 to 1:1 from 1 ½" holes drilled to a depth varying from five to eight meters. The holes were located along lines parallel to the dam axis covering the foundation area of the core with a distance of 2.5 meters between the lines. An amount of bentonite of 2% of the weight of cement was added to the mix.

VLIYANIE TSEMENTATSII NA DEFORMATSIONNYE SVOISTVA TRESHCHINOVATYKH GORNYKH POROD (INFLUENCE OF CEMENT GROUTING ON DEFORMATION PROPERTIES OF CRUMBLING ROCKS) P

Sapegin, D.D.

Gidrotekhnicheskoe Stroitel'stvo, no.5, p.26-30, May 1965.
Presents Soviet experience and data observed in tests of dam embankments on natural and concreted rocks. Investigations conducted by measuring displacements of rock surfaces and using static loading of rocks before and after grouting.

USE OF SPRAY-CONCRETE AND SURFACE GROUTING FOR CONSOLIDATION OF ROCK FOUNDATION OF ASWAN DAM ABUTMENTS (PRIMENENIE NABRYZG-BETONA I PLOSHCHADNOI TSEMENTATSII DLYA ZAKREPLENIYA SKAL'NOGO OSNOVANIYA BEREGOVYKH PRIMYKANII VYSOTNOI ASUANSKOI PLOTINY) P

Savin, V.I.

Hydrotechnical Construction, no.11, p.989-990, November 1968. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.11, p.25-30, November 1968.)
Surface cementation and grouting is used in order to line the rock foundation over the whole surface of abutment on the Aswan Dam.

THE RECONSTRUCTION OF THE STONY RIVER DAM

Scheidenhelm, F.W.

American Society of Civil Engineers, Transactions, vol.81, p.907-1023, 1917.
Contains a description of pressure grouting under footings (p.987-988).

METHOD AND COST OF SOLIDIFYING FISSURED ROCK BY GROUTING, ESTACADA DAM, OREGON P

Schreiber, H.V.

Engineering and Contracting, May 8, 1912.
General idea provided for drilling and grouting double line of holes 50 feet deep across entire valley to obtain the equivalent of a cut-off wall.

ALLUVIAL GROUTING AT BACKWATER DAM M

Scrimgeour, J., and Rocke, G.

The Engineer, p.729-730, 13 May 1966.
Discusses recent developments in alluvial grouting which allow construction of a reservoir at the site of the Backwater Dam. The earth-fill embankment was built to develop the water resources of the Lintranthen Catchment Area for Dundee Corporation.

BACKWATER RESERVOIR FOR DUNDEE CORPORATION WATERWORKS P

Scrimgeour, J.

Journal of the Institution of Water Engineers, vol.20, no.5, p.325-357, July 1966.
Description of site investigation and method of construction of earth dam with clay-cement grout cutoff placed by "manchette" method; alluvial grouting was commenced from each flank of valley, and in valley bottom embankment was constructed to keep drills above artesian water-levels.

CONSTRUCTION OF MORROW POINT POWER PLANT AND DAM P

Seery, J.D.

American Society of Civil Engineers, Journal of the Construction Division, CO1, p.47-58, March 1967, Paper 5154.
The general plan for grouting the rock foundation includes (1) the drilling and grouting at the rock foundation of the dam using low pressures at shallow depths; (2) deep curtain grout holes; (3) drilling and grouting from tunnels to extend the main grout curtain into the right and left abutments; and (4) drilling and grouting of the rock under the stilling basin and weir.

RECONHECIMENTO DE MACICOS ROCHOSOS, POR SONDAGENS, PARA O ESTUDO DAS FUNDACOES DE BARRAGENS (EXPLORATORY DRILLING IN ROCK MASSIFS FOR STUDY OF DAM FOUNDATIONS)

Serafim, J.L., and Seabra, F.M.

Tecnica, vol.34, no.315, p.45-52, October 1961.

EFFECTIVENESS OF THE PILE CUT-OFF ON SELEVIR DAM P

Sezginer, Yuksel, and Karacaoglu, Bekir

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.595-608.

Cast-in-situ piles were constructed in two stages. The first stage was filled with 3" aggregate and pressure grouted with cement. The overlapping second stage piles were drilled by a rotary machine and grouted in the same manner.

OBRA DAM FOUNDATION TREATMENT P, M

Sharma, O.D., Harkauli, A.N., and Sharma, H.D.

Indian Journal of Power & River Valley Development, vol.20, no.10, p.406-411, October 1970.

Grouting of foundation and intervening sand between diaphragms is discussed. Because of the highly jointed nature of foundation rock and presence of solution cavities, it was decided to grout the foundation rock all along the alignment of the diaphragm cut-off to form a deep and permanent impermeable curtain.

SOME CONSIDERATIONS CONCERNING UNDERSEEPAGE CONTROL FOR EARTH DAMS P

Sherard, J.L.

Conference on Recent Developments in the Design and Construction of Earth and Rockfill Dams, University of California, Berkeley, March 1968.

Describes and evaluates methods for underseepage control for earth dams.

TWO RECENT EXAMPLES OF RESERVOIRS CREATED ON DIFFICULT SOILS P

Silvestri, T., and Penati, S.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.873-898.

Construction at Gallo Matese Reservoir of a gravity concrete dam provided for the creation of a diaphragm by means of grout injections in the foundation rock, extension of the diaphragm along the left bank and grouting of the upper layer of limestone covered by alluvial deposits on the reservoir bottom.

FINAL FOUNDATION TREATMENT AT HOOVER DAM P

Simonds, A.W.

American Society of Civil Engineers, Transactions, vol.118, p.78-112, 1953, Paper 2537. (Also American Society of Civil Engineers, Proceedings Separate no.109, vol.77, December 1951.)

In the design of the Hoover Dam, the treatment of the foundation involved a design based largely on experience. Pressure grouting was anticipated to reduce seepage, to eliminate uplift pressure in the foundation beneath the dam and appurtenant structures, and to correct defects in the bedrock. In addition to the grouting treatment, a drainage system downstream from the grouted area was considered essential.

MOVEMENT OF BOULDER DAM DUE TO GROUTING P

Simonds, A.W.

Civil Engineering, vol.7, no.4, p.282-285, April 1937.

Boulder Dam consists of a large number of slender columns with vertical joints grouted under pressure to form a monolithic structure. Tells how measurements were made of the block deflection caused by grouting the vertical joints and notes the precautions taken to check excessive movements. Deflection curves, plotted by the author directly from gage readings, should prove helpful in guiding the work of arched dam structures elsewhere. A description of the cooling system used to dissipate the heat liberated by the setting up of the concrete is also included. The article constitutes the fifth and last of a group of papers on grouting work at Boulder Dam. The first appeared in September 1936.

ESTIMATION OF GROUT ABSORPTION IN FRACTURED ROCK FOUNDATIONS P

Sinclair, B.J.

Urbana, Illinois, University of Illinois, Doctoral Dissertation, 1972.

Discusses foundation grouting including factors affecting foundation groutability, measurement of groutability, effect of grout hole spacing on grout absorption, and estimation of grout absorption.

THE CONSTRUCTION OF CLARK DAM ON THE DERWENT RIVER, BUTLER'S GORGE, TASMANIA P

Slayter, V.A., and others

Journal of Institution of Engineers, Australia, vol.22, p.1-24, January-February 1950.

Description of construction of an arch-gravity structure. The preliminary grouting, both blanket and curtain grouting was at relatively low pressures, 25-35 psi, blanket grouting was done through a 10 ft cover of concrete. Contraction joints were grouted with air-separated cement.

ROCK FRACTURE SPACINGS, OPENINGS, AND POROSITIES C

Snow, D.T.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.94, SM1, p.73-91, January 1968; Paper no.5736.
Method described here is used to determine fracture porosity from permeability measurements in drill holes. If a porosity computed by this method is used to predict the volume of rock impregnated by a given volume of grout the result is likely to be conservative. The viscous and particulate nature of the grout will prevent it from filling the finer fractures; dilution along an irregular front will increase the grout volume, and even a water-like grout will penetrate to different distances proportional to the sizes of fracture openings. Volume predictions are likely to be more realistic for a chemical grout of low viscosity than for a grout having either a high viscosity or suspended particles.

FOUNDATION IMPROVEMENT OF AN ARCH DAM BY SPECIAL CONSOLIDATION GROUTING P

Soejima, T., and Shidomoto, Y.

Congress of the International Society of Rock Mechanics, Second, Belgrade, 1970, Proceedings, vol.3, Theme 6, no.6, p.167-174.
Conventional consolidation, curtain grouting and special consolidation grouting of the core of the left bank was deemed necessary for stability for the Shimouke Arch Dam on Kyushu Island, Japan. Inverted pendulums and rock deformeters observed rock movements caused by grouting. In-situ tests indicated that cement grouting would improve deformability of poor rock.

THE HINCKSTON RUN DAM

Sonder, Harrison

American Society of Civil Engineers, Transactions, vol.78, p.520-535, 1915.
Discussion of H.A. Rands' Paper on Estacada Dam (ASCE Transactions, vol.78, p.447-489, 1915). This dam, built of earth upstream and cinders downstream, has puddled core and concrete core wall extending 30 ft down. Grouting extended it to slate strata.

SOUTH AFRICA'S LARGEST ARCH DAM P

Concrete, Journal of the Concrete Society (London), vol.2, no.4, April 1968.

Contact grouting performed. Grouting pressure 80 psi. Consolidation grouting at 25 psi. Curtain grouting through holes 200 ft deep. Contraction grouting to render the structure monolithic was also carried out.

EARTH AND ROCKFILL DAM ENGINEERING M

Sowers, G.F., and Sally, H.L.

University of Roorkee, Asia Publishing House, India, 1962.

Discusses the use of grouting in the construction of soil and rockfill dams, including the use of grout curtains and blankets. Describes all types of grouting materials.

FOUNDATION EXPERIENCES IN N.S.W. DAMS P

Stafford, C.T.

Australia-New Zealand Conference on Soil Mechanics and Foundation Engineering, 4th, Adelaide, 1963, Proceedings, p.115-125.

Drainage problems and grouting procedures at three dams in N.S.W., Australia. Discusses geological details, site investigation, drainage conditions and systems of blanket and curtain grouting.

CONSOLIDATION WORK FOR THE GRANCAREVO DAM FOUNDATION

Stojic, Peter

Journal of the International Society of Rock Mechanics, vol.3/1, p.24-33, 1965.

123m high arch dam in the Karst region of Yugoslavia. Deep grout curtain upstream; shallow grout curtain downstream, and a 10-20m deep consolidation grouting blanket covering the contract area of the dam. Stratified lias limestone underlying damsite contained scattered marl-clay and coal-clay beds.

STRENGTHENING THE FOUNDATIONS OF KERKINI DAM P

Civil Engineering and Public Works Review, vol.59, no.694, ICOLD Supplement, p.33, May 1964.

Injection of cement and bentonite improves permeability and stability of the foundation soils of a 30-year-old irrigation dam in Macedonia. Downstream stilling pond was also improved.

FOUNDATION TREATMENT FOR EMBANKMENT DAMS ON ROCK

Stroppini, E.W., Babbitt, D.H., and Struckmeyer, H.E.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.98, no.SM10, p.1073-1079, October 1972, Paper 9274.
The practice in abutment and foundation treatment for high embankment dams on rock as used by The Department of Water Resources is described with reference to Oroville Dam, Cedar Springs Dam, and Pyramid Dam. There was very minor leakage through the foundation indicating an excellent grouting job was performed.

INFLUENCE OF GEOLOGICAL CONDITIONS ON UPLIFT P

Stuart, W.H.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, no.SM6, Part 1, p.1-17, December 1961, Paper 3008.
The selection of uplift assumptions at the base of dams has varied widely among designers. The values selected for most dams constructed in past 20 years have been conservative, as indicated by uplift observations. In several instances uplift pressures higher than design assumptions have been observed. A comparison is made of the geological conditions and the uplift pressures at several dams. The influence of grouting procedures is discussed.

GROUTED CUTOFF AT ROCKY REACH DAM P

Swiger, W.F.

American Society of Civil Engineers, Structural Engineering Conference, May 8-12, 1967, Preprint 507.
During the first five years of service, no detectable change in the effectiveness of the cutoff was observed in piezometric levels recorded in gravels upstream and downstream of cutoff.

PREPARATION OF ROCK FOUNDATIONS FOR EMBANKMENT DAMS

Swiger, W.F.

Embankment-Dam Engineering, Casagrande Volume, ed. by R.C. Hirschfeld, p.355-363. New York, John Wiley and Sons, 1973.
This paper discusses grouted cutoffs, extent of grouting, single-row and multi-row patterns, depth and sequence of boring, problems due to soluble rocks, field control, drilling procedure, grouting equipment and procedure, composition and mixing of the grout, excessive injection pressure, and travel of the grout.

SOME CONSTRUCTION ASPECTS OF BENMORE EARTH DAM M

Tait, G.A.

Australia-New Zealand Conference on Soil Mechanics and Foundation Engineering, Fourth, University of Adelaide, August 19-23, 1963, Proceedings, p.76-80.

Rolled earth fill dam structure is described. The foundation grouting, development of borrow pit for earth dam core, hauling and placement of core and shoulder material are discussed.

DAM FOUNDATIONS: RECENT VICTORIAN PRACTICE FOR EARTH AND ROCKFILL DAMS P

Taylor, F.G.

Australia-New Zealand Conference on Soil Mechanics and Foundation Engineering, Fifth, Auckland, 1967, Proceedings, p.132-140.

Review of techniques for providing adequate water tightness and foundation material stability and preventing piping failure--such as impervious cutoffs, grouting and upstream blankets. Some information is in chart and formula form.

DAM FOUNDATION ON SHEETED GRANITE P

Terzaghi, Karl

Geotechnique, vol.12, no.3, p.199-208, September 1962.

Consolidation grouting over the entire rock surface exposed in the core trench preceded the construction of the grout cut-off. The grouting operations on the bottom of the cut-off trench were followed by those on the two abutments above the level of the valley floor. On the basis of the results of the observations during the drilling and grouting operations it can be considered certain that grout has plugged all those open spaces through which large quantities of water could escape or which could close up under the influence of the weight or the lateral pressure exerted by the dam.

MISSION DAM; AN EARTH AND ROCKFILL DAM ON A HIGHLY COMPRESSIBLE FOUNDATION P

Terzaghi, Karl, and Lacroix, Y.

Geotechnique, vol.14, no.1, p.14-50, March 1964.

Deals with the design, construction and performance of an earth and rockfill dam on the Bridge River in British Columbia. The site is underlain by two very pervious aquifers. Under the major portion of the dam site these are separated by a thick stratum of highly

compressible clay. A deep grout cut-off through the lower aquifer, extending to a maximum depth of about 520 feet and a sheet pile cut-off through the upper aquifer control seepage through the foundation. The nature of the available construction materials and the anticipated large differential settlements led to the design of a zoned type of embankment. Significant details of construction and performance of the dam during the first three years of service are described.

THE LOWER RESERVOIR OF THE RONKHAUSEN PUMPED STORAGE SCHEME M

Thomann, G.

Tiefbau, vol.11, no.2, p.71-77, 1969.
Structure of the body of the dam and bitumen waterproofing, subsoil waterproofing, undersluice construction, flood channelization, water level control, and bank safety work are described. After exhaustive tests a 28m-high rockfill dam was built, with varying permeability zones. The outer sealing was asphaltic concrete. Data on injection pressures and injection stages are included.

ROENKHAUSEN PUMPED-STORAGE PROJECT P

Thomann, G.

Water Power, vol.21, no.8, p.289-296, August 1969.
In the construction of this power station, an accessible tunnel was constructed along the foot of the dam on the upstream side, through which the grouting was injected through injection pipes.

STRENGTHENING OF JOHN HOLLIS BANKHEAD DAM P

Thompson, F.G.

Civil Engineering, vol.39, no.12, p.75-78, December 1969.
Post-tensioned anchors provided a neat solution for strengthening a potentially unstable spillway. Steel wire anchors were placed deep into the foundation from the spillway gallery, post-tensioned, then grouted. After each anchor was lowered into the hole, the bottom 30 ft of the anchor was grouted into the foundation. Grout was pumped into the holes through the grout pipe in the center of the anchor wires.

THREE PHASES OF MISSION DAM C, P

Engineering News-Record, vol.166, no.26, p.33-35, June 29, 1961.
Soletanche used its grout formula for the first time in North

America at Mission Dam. The grout is intended to protect the earth-fill from seepage through a sand and gravel aquifer between bedrock and a natural clay stratum under the dam. A clay-cement grout with a high cement-water ratio was used, followed by a phosphate deflocculated clay stabilized with silicate for the center line.

COMMENTS ON THE CONSTRUCTION OF GROUTED CURTAINS P

Tkany, Z.

Vodni Hospodarstvi (Prague), vol.20, no.1, Series A, p.7-14, 1970.
Discusses drilling and grouting operations used in creating grouted curtains--including mistakes and shortcomings which often occur. Drilling procedures and the results achieved by shot-drilling and diamond drilling are compared.

WATERTIGHT CURTAIN OF LA AMISTAD DAM (MEXICO) P

Trabadello, R.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.453-467.
Discusses grouting procedures for the Amistad Dam on the Rio Grande River between Mexico and Texas. Qualitative and quantitative techniques, spacing and depth of the grout holes, selection of grout mixes, and control of the grouting operations.

NEW TITTESWORTH DAM P

Twort, A.C.

Journal of the Institution of Water Engineers, vol.18, no.2, p.125-179, March 1964.
Proposed design for heightening of existing earth dam; placing methods and grouting are discussed, as well as installation of pore-water pressure cells; underdrain flow, settlement, and movement.

LES TRAVAUX D'ETANCHEMENT DES TERRAINS AU BARRAGE DE FOUM-EL-GHERZA M

Uguet, D.M.

International Congress on Large Dams, 6th, New York, 1958, Transactions, Communication no.15, p.1-10.
In French.

FOUNDATION DRILLING AND GROUTING. P

U.S. Army. Corps of Engineers

Washington, D.C., Guide Specification CE-1305.01, October 1959; Amendment 2, October 1964.
This guide specification covers drilling exploratory holes, drilling drain holes, making grout connections, mixing and injecting the grouting materials, patching the finished grout holes, disposal of waste water and waste grout, and cleanup of grout galleries and shafts. Drilling and grouting equipment is also covered.

FOUNDATION PUMPING TESTS C, P

U.S. Army. Corps of Engineers

Washington, D.C., Civil Works Technical Letter 63-16, 4 December 1963.
Letter indicating that pumping tests are to be made to verify foundation permeability for all embankments under construction as being designed where grouting has not been considered.

ALVIN R. BUSH DAM, KETTLE CREEK, PENNSYLVANIA; REPORT ON REGROUTING OF LEFT ABUTMENT P

U.S. Army Engineer District, Baltimore

Baltimore, Md., December 1976. 2 vols.
Gives history of seepage at Bush Dam (Susquehanna River Basin). Discusses remedial treatment program including drilling of grout holes and grouting of foundation and exploratory program. The regrouting of the left abutment was completed by June 1974. Evaluation of findings indicates the seepage path or paths through the left abutment rock have been successfully grouted.

REPORT ON GROUTING AND DRAINAGE, NORFOLK DAM P

U.S. Army Engineer District, Little Rock

Little Rock, Ark., 1944.
This report is written in order to have on record a description of the procedures that were used, the difficulties that were encountered, and the quantity of cement that was used in grouting the foundation for Norfolk Dam. Excerpts from conference notes and memoranda pertaining to grouting at Norfolk Dam are contained in the appendix. Grouting of the foundation rock was performed for two purposes: (1) to consolidate and strengthen the foundation at those places where it was deemed necessary to prevent possible settlement of foundation

rock, and (2) to form a grout cut-off curtain under the upstream side of the dam to minimize leakage through the rock. All grouting at Norfolk Dam was done with a mixture of portland cement and water. Pressures under which the grout was injected into the foundation rock were determined, for the most part, on the basis of one pound per square inch pressure for each foot of rock, and/or concrete above the zone being grouted.

CUMBERLAND RIVER BASIN, KENTUCKY LAUREL RIVER RESERVOIR; INTERIM REPORT ON FOUNDATION TREATMENT--LAUREL DAM

U.S. Army Engineer District, Nashville

Nashville, Tenn., 1973.

FINAL REPORT, ASPHALT GROUTING OPERATIONS, CHICKAMAUGA PROJECT LOCK, TENNESSEE RIVER M

U.S. Army Engineer District, Nashville

Nashville, Tenn., 1937.

Contains basically same information as in the preliminary report. Some additional information on the asphalt grouting of the lock cofferdam foundations, and leaks in the lower cofferdam, cells and the spillway excavation. Also contains photographs illustrating details of the grouting operations, as well as plan of lock and cofferdam.

PRELIMINARY REPORT, ASPHALT GROUTING OPERATIONS, CHICKAMAUGA PROJECT LOCK, TENNESSEE RIVER M

U.S. Army Engineer District, Nashville

Nashville, Tenn., 1937.

The necessity for careful treatment of foundations was recognized early in the first stages of design and, with this fact in mind, the Tennessee Valley Authority conducted various experiments in the sealing of foundations. Among the various experiments conducted, was the use of asphalt for grouting and sealing foundations. The experiment consisted of grouting a 3" diamond drill hole, 100 feet deep, through about 43 feet of sandy loam overburden and then thoroughly investigating the grouted area by means of core drilling. This hole was chosen for the experiment because the general character of the rock was considered typical of the foundations for the project. The main feature of the patented system of the American Asphalt Grouting Company, is the use of a "hot" wire inside of the hole being grouted, to keep the asphalt in a liquid state. Use of asphalt as a grouting

material leaves a great deal to be desired. Due to its high shrinkage factor, asphalt grout fails to completely seal any void, cavity, or seam. However, it is true that the asphalt grouting work on this project was done under adverse conditions. It is not possible to state at this time the exact value of the asphalt grouting done on this project. It is believed the asphalt grouting was responsible for some of the success experienced in the holding of the cofferdam against several high stages of the river, as it served to tighten up the overburden and diminish the size of the leaking seams.

WOLF CREEK DAM, CUMBERLAND RIVER, KENTUCKY; REPORT OF COMPLETION OF SUBSURFACE INVESTIGATIONS

U.S. Army Engineer District, Nashville

Nashville, Tenn., 1974.

WOLF CREEK DAM, CUMBERLAND RIVER, KENTUCKY; REPORT OF COMPLETION OF SUBSURFACE INVESTIGATIONS (PHASE 1)

U.S. Army Engineer District, Nashville

Nashville, Tenn., 1974.

WOLF CREEK DAM, CUMBERLAND RIVER, KENTUCKY; REPORT OF COMPLETION OF SUBSURFACE INVESTIGATIONS (PHASE 2)

U.S. Army Engineer District, Nashville

Nashville, Tenn., 1974.

WOLF CREEK DAM, CUMBERLAND RIVER, KENTUCKY; REPORT OF COMPLETION OF SUBSURFACE INVESTIGATIONS (PHASE 3)

U.S. Army Engineer District, Nashville

Nashville, Tenn., 1975.

Evaluation of numerous investigations and studies concerning the foundation conditions of Wolf Creek Dam has indicated that a serious seepage problem exists. Extensive remedial grouting was performed to temporarily control this seepage. In order to form a permanent cutoff, a concrete diaphragm wall extending through the embankment and solutioned limestone is to be installed.

WOLF CREEK DAM, CUMBERLAND RIVER, KENTUCKY; REPORT OF REMEDIAL WORK 1968-1970

U.S. Army Engineer District, Nashville

Nashville, Tenn., 1973.

REVIEW OF LECTURES AND DISCUSSIONS, OHIO RIVER DIVISION CONCRETE SCHOOL P

U.S. Army Engineer District, Pittsburgh

Conducted at Pittsburgh, Pennsylvania, January 23-26, 1935.
Grouting is the usual method of correcting the defects in rock foundations for dams. A section of the foundation along the upstream edge of the dam must be made completely impervious so that no water can get through it. The grout is a mixture of portland cement and water, the proportions varying from one-half bag to five bags of cement to three cubic feet of water. The grout curtain must prevent any water passing through the foundation, under or around the dam, and should accomplish this result for a least expenditure of money. A row of holes, usually 1-1/2 inches in diameter, 25 feet deep, and spaced about 25 feet apart, is drilled into the rock along the line to be grouted. Holes for the high pressure grouting can now be drilled to the full depth of the grout curtain. Grouting can usually be fitted into the construction program so that it will not interfere with other parts of the work.

LOOKOUT POINT DAM, FOUNDATION REPORT P

U.S. Army Engineer District, Portland

Portland, Ore., 1 February 1959.
Section VI--Grouting and Drainage--discusses drilling and grouting operations and makes recommendations for improvements in the actual grouting operations and in the construction work or design preceding such operations. Two distinct problems were faced in the foundation grouting. The first was in connection with contact grouting beneath the impervious clay core of the embankment section. The second was in connection with curtain grouting beneath the concrete section. All grouting was performed on a one-shift basis. Because of very low grout takes, this operation generally consisted of making a connection, mixing a few sacks of grout, pumping it into the pipeline, pumping to refusal and clearing out the lines.

FOLSOM PROJECT, AMERICAN RIVER, CALIFORNIA--EXPERIMENTAL GROUTING OF RIVER GRAVELS--INTRUSION-PREPAKT TEST SECTION P

U.S. Army Engineer District, Sacramento

Sacramento, Calif., August 1951.

The economical construction of a reasonably watertight cutoff wall is complicated by nests of large boulders along the sides of the channel and the uneven granite bedrock. In considering methods of controlling the underground flow of water beneath the cofferdams, it was decided to try, on an experimental basis, consolidating the gravels into a concrete cut-off wall by jetting out fines and intruding a grout to fill the voids. It is the purpose of this report to describe the construction techniques employed in such experimental work, the problems and difficulties encountered, the results of exploratory drillings and pressure-leakage tests, the damage caused to the wall by subsequent floods, and to summarize the results of this experiment.

FOLSOM PROJECT, AMERICAN RIVER, CALIFORNIA; SUPPLEMENT NO.1 TO EXPERIMENTAL GROUTING OF RIVER GRAVELS, INTRUSION-PREPAKT TEST SECTION P

U.S. Army Engineer District, Sacramento

Sacramento, Calif., February 1952.

This supplementary report describes additional findings on the behavior of grout in the experimentally grouted section of the cut-off wall for the Folsom upstream cofferdam. The test section was revisited and photographs were taken. Any future attempts to develop this technique into a feasible method should consider, in addition to the recommendations and conclusions in the report, the following points: (1) the exact nature of the material to be jetted and grouted should be known; this exploration should be particularly directed toward the detection of strata of open gravels; (2) the kind and amount of grout and the rate of pumping to use at a given hole should be based upon a consideration of the nature of the materials, the depths of any pervious stratum and possible underground water flow; (3) a maximum limit should be established for the amount of grout permitted to be pumped into any one hole. For grouting an open stratum of segregated gravel, economy would dictate the use of a highly sanded grout; (4) the grout hole spacing and pattern of laying out the holes should be based upon the gradation of the aggregate to be grouted and the anticipated or desired flow of grout. Under the circumstances, it is believed an intermediate set of test holes should be planned to follow along behind the original grout holes. These intermediate holes should also be jetted and grouted. Sufficient additional exploratory holes should then be drilled to assure that the wall is completely grouted.

GILLHAM LAKE, COSSATOT RIVER, ARKANSAS; REPORT GILLHAM DAM FOUNDATION, PART III: EMBANKMENT AND FOUNDATION GROUTING P

U.S. Army Engineer District, Tulsa

Tulsa, Okla., May 1975.

The grout curtain was formed by drilling and grouting a single line of holes, varying in depth from 20 to 100 feet. The primary holes were drilled to full depth, washed, pressure tested, and grouted in accordance with the "stop grouting, split spacing" method. This method requires the holes to be drilled to final depth and grouted by stops through a packer set at successively shallower depths. The secondary holes are then located midway between the primary holes. The split spacing continues until the holes are determined to be tight.

HUGO LAKE FOUNDATION EMBANKMENT, SPILLWAY AND FOUNDATION GROUTING C

U.S. Army Engineer District, Tulsa

Tulsa, Okla., August 1975.

Foundation grouting techniques to be used in embankment and spillway at Hugo Lake (Oklahoma) are discussed.

CHEMICAL GROUTING INVESTIGATIONS OF NAVAJO SANDSTONE C

U.S. Bureau of Reclamation

Denver, Colo., Report No. C-1064 A, November 23, 1966.

Conventional PC grouting methods would not effectively seal Navajo Sandstone and Glen Canyon Dam. Lab and field tests initiated for determining practical methods and techniques for chemical grouting of this sandstone. Results: (1) Essential to investigate interaction of chemical grouts with water and sandstone; (2) need to select appropriate chemical grout with desired setting time by titration method; (3) injection of one solution chemical grout (silica or silica salt) by gravity flow and/or by pressurized air head through a rubber diaphragm is preferable to the use of pressure provided by a diesel engine triple pump; (4) acceptance of chemical grout by the Navajo sandstone system cannot be considered as a measuring factor for evaluating the success of the grouting operation; success of chemical grouting depends also on the permeability of the sandstone, viscosity of chemical grout solution, and the grout pressure employed.

FLAMING GORGE DAM AND POWERPLANT. TECHNICAL RECORD OF DESIGN AND CONSTRUCTION, DENVER, COLORADO — P

U.S. Bureau of Reclamation

Denver, Colo., January 1968.
Grouting rock foundations of the dam and spillway-intake structure through low pressure and high pressure; grouting the rock foundation of the dam and spillway intake structure with high pressure; grouting rock surrounding upstream and downstream portions of the spillway tunnel and around the diversion tunnel plug; grouting the back fill concrete placed in the tunnels excavated for cutoffs in shale seams; placing mortar or grout by grouting methods to complete the placement of concrete lining in tunnels.

GLEN CANYON DAM SITE, ARIZONA — C

U.S. Bureau of Reclamation

Denver, Colorado, Field Trip Report No. 745.
Sodium silicate and various reagents--$NaHCO_3$, $NaAlO_2$, $Ca Cl_2$- one shot chemical grout. Report prepared by J.P. Elston.

PRESSURE GROUTING — P

U.S. Bureau of Reclamation

Denver, Colo., Technical Memorandum No. 646, June 1957.
This is a 5-part memorandum covering the following topics: (1) Foundation grouting; (2) grouting contraction joints in dams; (3) pressure grouting equipment; (4) pressure grouting the foundation of Deer Creek Dam; (5) grouting contraction joints at Seminoe Dam.

TESTS ON THE JOHN MARTIN FOUNDATION SANDSTONE — C

U.S. Bureau of Reclamation

Denver, Colo., Laboratory Report No. C-208, June 3, 1943.
The grout tests described in this report were made to investigate the feasibility of reducing or stopping the flow of water through the foundation sandstone rock at John Martin Dam on the Arkansas River in Colorado. Cement or other "solids in suspension" grouts are unsuitable for grouting fine-grained sandstone. Excellent penetration was obtained with the "single-shot" chemical grout composed of sodium aluminate and sodium silicate and the flow of water through the sandstone was materially reduced by this grout.

THE FOUNDATION AND SEEPAGE PROBLEMS OF ALTINAPA DAM P

Ural, O.N., Sertgil, S., and Ozil, S.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.583-594.
The geology and the foundation conditions of the Altinapa Damsite are such that provisions against seepage are connected with the foundation stability and the safety of the dam. The limestone surface is usually inspected and all large cracks, etc. are filled with concrete. This surface is then treated with thick cement-water grout.

URUGUAY TRIES GROUTING CRACKS IN DAM P, M

Engineering News-Record, vol.181, no.16, p.48-51, 17 October 1968.
Cracks in Canelon Grande Reservoir grouted with expansive PC grout. Epoxy used as coating on chipped out portions--wet prior to dry packing, also grout pipes sealed in with epoxy.

EFFECTIVENESS OF CUT-OFFS UNDER THREE EARTH DAMS P

Vargas, M.

Pan American Conference on Soil Mechanics and Foundation Engineering, 4th, San Juan, P.R., June 1971, Proceedings, vol.2, Selected Papers, p.257-273.
Three types of cut-offs used in three Brazilian earth dams are described. The first one at Limoeiro Dam is a positive cut-off construction of a concrete wall and grouting in fissured rock. In the Euclides da Cunha Dam cut-off the concrete wall was supplemented by a drainage and grouting gallery. At the third, grouting was ommitted. The effectiveness of these three types of cut-off is examined and it is concluded that the good control of piezometric water level is due entirely to the drainage deposition and not to the grouting.

CRACKING AND EROSION OF THE ROLLED CLAY CORE OF BALDERHEAD DAM AND THE REMEDIAL WORKS ADOPTED FOR ITS REPAIR

Vaughan, P.R., and others

International Congress on Large Dams, 10th, Montreal, 1-5 June 1970, Transactions, vol.1, p.73-93.
Balderhead Dam, a 48 m high shale-fill dam with boulder-clay core, developed high seepage flow, sink holes, and localized crest settlements on first impounding. Cracks opened and kept open in the core by water pressure permitted water flow through the cracks with subsequent erosion and propagation of the crack surfaces. These cracks

closed on reduction of water pressure due to reservoir drawdown. Remedial works consisted of core grouting, to increase total earth pressures and prevent further hydraulic fracturing, together with the introduction in trench under bentonite of a plastic clay-cement concrete diaphragm wall in the core as a materials and water barrier in the damaged areas.

DESIGN OF KARADJ ARCH DAM P

Veltrop, J.A., and Wengler, R.P.

American Society of Civil Engineers, Journal of the Power Division, vol.90, no.PO1, p.1-32, March 1964, Paper 3827.

Design, stress analysis and model studies of this 590 ft high thin arch dam are discussed. The foundation rock was strong, but joints and fractures required careful grouting, beginning with initial low-pressure grouting, followed by low-pressure consolidation grouting, and completed with a high-pressure curtain.

INVESTIGATION OF LEAKAGES AT PIDIMA DAM ON RIVER LADHON IN THE PELOPONESE, GREECE P

Vlastos, K.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.3, p.457-475.

Pidima Dam is a hollow element, concrete gravity dam on the River Ladhon in Central Peloponese. During its construction, certain springs were met at the deepest part of the foundations. Supplementary grouting restricted their magnitude but did not eliminate all flow from them. In the second year of operation, an investigation was made of the outflows from the springs as water was accumulating at the toe of the dam and inside the central element. The permeability of the rock under the dam was reexamined in the light of the data obtained during the execution of the test borings and of the grouting curtain. The geology of the rock was also reviewed. The investigation answered questions as to whether the leakages constituted a danger to the stability of the dam and whether their elimination of limitation by grouting was possible and economically advisable.

PERMEABILITY AND GROUTING MEASURES IN THE CONSTRUCTION OF THE TINAJONES RESERVOIR IN NORTHERN PERU

Von Esbeck-Platen, H.H.

Symposium, Percolation Through Fissured Rock, Stuttgart, September 1972, Proceedings, p.T4-B, 1-10; sponsored by International Society

for Rock Mechanics and International Association of Engineering Geology. Essen, Deutsche Gesellschaft fur Erd- und Grundbau, 1972.

In the Tinajones Reservoir for the abutments of the main dam and the foundation of three auxillary dams extensive grouting of the substrata had to be made for sealing the rocks. In spite of relatively high water absorptions in the water percolation tests, a sufficient take in the fissures and joints could be achieved only with the addition of Betonplast as a plastifying agent.

GROUT CURTAIN IN GRAVEL AT HUNDERFOSSEN POWER PLANT P

Wabakken, A.

International Congress on Large Dams, 9th, Istanbul, 4-8 September, 1967, Transactions, vol.1, p.767-774.

Seepage at Hunderfossen Dam in Norway. Grout curtain using mainly bentonite/cement grout was placed which was eighty percent effective when completed. Later measurements have indicated further improvement.

GEOLOGIC EXPLORATION AND FOUNDATION TREATMENT, WILLIAMS FORK DAM, POWER PLANT, AND WEST DIKE, COLORADO P

Wahlstrom, E.E.

Geological Society of America, Engineering Geology Case Histories No.4, p.9-18, 1963.

Placing of concrete on bedrock in the dam foundation was preceded by consolidation grouting to fill and seal all visible fractures in the bedrock with grout by means of holes dipping about 60 degrees and drilled to an inclined depth of thirty feet. Pressures used during grouting were commonly less than 100 pounds per square inch, and for most holes, about fifty psi. The cut-off, curtain grout holes were drilled through nipples set in concrete fillets along the upstream toe of the dam. Each hole was directed at angles that would permit emplacement of a grout curtain under the upstream portion of the dam. Movement of grout into the rocks at various depths in the grout holes was controlled by setting a packer at successively shallower depths. Grout was pumped into the portion of the hole below each packer setting to the point of practical refusal.

TREATMENT OF HIGH EMBANKMENT DAM FOUNDATIONS P

Walker, F.C., and Bock, R.W.

American Society of Civil Engineers, National Water Resources Engineering Meeting, Phoenix, Arizona, January 1971, Preprint No.1339.

AD-A057 831 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 11/2
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JUN 78 R PETERSON, J GRIFFITH, E DUNLAP
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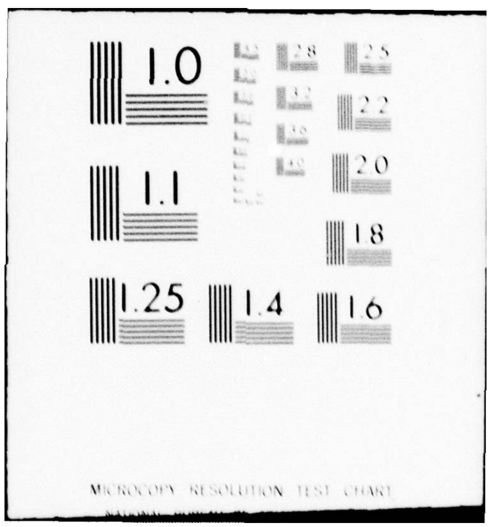
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MICROCOPY RESOLUTION TEST CHART

Describes geology of the reservoir area and the dam site for three high earthfill dams founded on rocks. Foundation treatment includes excavation to the bedrock, grouting, and other subgrade improvements to reduce seepage.

FOUNDATION PRACTICES FOR TALBINGO DAM, AUSTRALIA P

Wallace, B.J., and Hilton, J.I.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.98, no.SM-10, p.1081-1098, October 1972, Paper 9273.
Both blanket and curtain grouting were performed as an integral part of the foundation treatment of Talbingo Dam.

EFFECTIVE SEALING OF WATER DAMS BY CEMENTATION

Waterhouse, F.N.

Concrete and Construction Engineering, vol.10, p.6, June 1915.

EXPERIMENTAL GROUTING INVESTIGATION FOR CHIEF JOSEPH DAM P

Wells, J.M.

American Concrete Institute Journal, vol.21, p.361-376, January 1950.
Laboratory studies of grout mixtures, techniques, and efficacy of grout treatment for seepage problem.

RESULTATS DE L'OBSERVATION DES SOUS-PRESSIONS DU BARRAGE DE L'ALTO RABAGAO (PORTUGAL) (RESULTS OF THE OBSERVATION OF UPLIFT PRESSURE AT ALTO RABAGAO DAM (PORTUGAL)) P

Weyermann, W.J.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.369-390.
Reports on the peculiar records of the uplift pressures which appeared to be a consequence of the grouting and drainage of the foundation work. Comments are added on the evolution observed over three years of dam exploitation. A short description of the consolidation grouting is given. The cement grout was injected only after the joints of the rock had been washed out thoroughly. The impermeabilization of the granite was done by means of cement grout and silicates through boreholes arranged in a single-row grout curtain. The quantities of absorbed materials are shown. In French.

ROCKFILL DAMS; FOUNDATION TREATMENT OF PARADELA C, P

Weyermann, W.J.

American Society of Civil Engineers, Journal of the Power Division, vol.84, no.PO4, August 1958, Paper 1748.

Foundation conditions at the site of the Paradela Dam in Portugal and the various problems they presented are described. The paper discusses the arrangement of grout curtains and other treatment carried out to suit the geological conditions and presents performance data on seepage control.

WHEN YOU CONSTRUCT DAM AND LATER WANT TO MAKE IT HIGHER WITH GREATER STORAGE CAPACITY--BUILD BIGGER DAM OVER SMALL DAM P

Pacific Builder and Engineer, vol.69, no.9, p.66-68, September 1963.

Discusses the construction of an earthfill dam over the present concrete dam; includes grouting considerations.

THE DESIGN OF CETHANA CONCRETE FACE ROCKFILL DAM

Wilkins, J.K., and others

International Congress on Large Dams, 11th, Madrid, 11-15 June 1973, Transactions, vol.3, p.25-43.

Contains a brief discussion of foundation grouting. Grouting of the foundation was carried out to provide an impervious zone of consolidated rock to a depth of 8 m below the plinth foundation surface and to provide a grout curtain to a depth equal to half the head.

WORK GOES ON ALL WINTER UNDER CORE-TRENCH COVER P

Construction Methods and Equipment, vol.48, p.89-91, October 1966.

Foundation grouting under winter conditions made possible by covering the core trench area of a dam in Wisconsin with a heated plastic shelter. Area was kept dry by a modified four-stage dewatering system. Briefly discusses drilling and grouting procedures. Illustrated by ten photographs.

DAM GETS FACE LIFTING P

Young, H.W.

Welding Engineers, vol.33, no.5, p.46-48, 51, May 1948.

Report on welding and other operations employed in repair of upstream face of Colorado's Barker Dam; concrete slabs were fastened to dam face by lap welding steel dowels embedded in slabs to steel anchor bars grouted onto face; concreting and grouting practices, space between face of dam and slab wall was filled with preplaced aggregate concrete.

II.-BRIDGES

ANCIENT MASONRY BRIDGE SAVED BY DOUBLE JEOPARDY RESCUE OPERATION — P

Engineering News-Record, vol.175, no.4, p.20-21, 22 July 1965.
Great Northern Railway's Bridge, Minneapolis. Stone masonry bridge, weakened by age and flooding, repaired by grouting. Pier subsidence, rebuilding of footing with grouted piling and packed concrete.

BRIDGE REPAIR ON CANADIAN PACIFIC RAILROAD — P

Canadian Engineer, vol.25, p.12, September 17, 1914.
Serious crack developed in swing bridge crossing Sault Ste. Marie Ship Canal, Ontario. Cement grout was poured into cracks.

SAVING OF ROTTING CONCRETE BRIDGE - CEMENT INJECTED UNDER STEAM PRESSURE

Brown, H.P.

Scientific American, vol.131, p.178, September 1924.

FOUNDATION ON WELLS OF CERTAIN BRIDGE PIERS AT THE BORA BALTEA BORDER TRAVERSING LARGE BLOCKS AND ALLUVIAL DEPOSITS AFTER SUBSOIL STABILIZATION (TORINO-AOSTA HIGHWAY, ITALY) — C, P

Grasso, F.

International Congress of International Association of Engineering Geologists, First, Paris, 1970, Proceedings, vol.1, p.593-600.
Describes principles--including injections of cement, bentonite and sodium silicate solutions for strengthening and waterproofing--that have governed the technique of well foundations.

GROUTING MASONRY ARCHES IN HAMBURG

Engineering Record, p.258, September 3, 1910.

GROUTING THE ARCHES OF OLD STONE VIADUCT

Engineering News, vol.69, no.23, p.1184, June 5, 1913.
Discusses repair of cracks in arches along Paris-Bordeaux Railway.

METHOD OF GROUTING FOUNDATION FOR HIGHWAY BRIDGE

Engineering and Contracting, vol.60, p.994-995, November 7, 1923. Discusses grouting foundation of highway bridge on the Yadkin River in North Carolina. The seams were grouted after the footing was poured.

CONSOLIDATION OF LOIRE SAND BY INJECTIONS UNDER THE FOUNDATIONS OF THE BRIDGE OF SAUMUR P

Peignaud, M.

Bulletin de Liaison des Laboratoires des Ponts et Chausses, no.51, 1971, p.165-181.
Describes the foundations system of 200-year-old Cessart Bridge in France. Grouting of foundation with cement-bentonite grout followed by resin is described. This arrested the movement of the pier and consolidated foundation as a whole.

DIE INSLANDSETZUNG DER GEWOELBTEN EISENBAHNBRUECKE UEBER DAS BEUTHENER WASSER BEI GLEIWITZ P

Roloff

Bautechnik, vol.15, no.34, p.437-440, August 6, 1937, and no.54, p.722, December 17, 1937 (discussion).
Strengthening of old concrete arch bridge, consisting of two 12 m spans, at Gleiwitz, Germany, by extensive cement grouting. In German.

SPITZEN-VERPRESSUNG VON GROSSBOHRPFAHLEN (POINT GROUTING OF LARGE BORED PILES) P

Schmitt, K.

Bautechnik vol.48, no.2, p.44-47, 1971.
Describes the foundation of two abutments for a railway bridge. The piles for the abutments were driven using the Holzmann Lining System. Grouting under the tip of the piles was performed to obtain minimum settling. In German.

SPECIAL GROUT BAGS ACT AS FORMS AND RIPRAP C, P

Railway Track and Structures, vol.67, no.2, p.20-21, February 1971.
Discusses the use of grout bags filled with structural cement mortar which were used to fill the void under a washed-out bridge pier. Bagpipe "Groutainers" are flexible, porous grout containers

that are tailor-made to fit job-site requirements. The "Groutainers" are filled with structural cement mortar and inflated to conform to the size and configuration of the cavity to be repaired. The porous containers are designed to provide excellent bonds with adjacent "Groutainers" and existing materials. The finished product becomes a cast-in-place structural unit for supporting pier loads and may serve as riprap for the prevention of future scour.

A THREE-HINGED CONCRETE ARCH BRIDGE OVER THE DANUBE

Engineering News, p.35, January 9, 1902.
Experiments first conducted as to feasibility of converting water bearing gravel into mass of concrete by grouting.

UNDERWATER CONCRETING OF BRIDGE BEGINS WITH GROUTING OPERATION P

Contractors and Engineers Magazine, vol.63, no.10, October 1966.
Seventy-two holes grouted with three yards of grout each. Seventy-two dowels were grouted to shale rock (with quartz). Grout mix was Type II cement, sand, Intraplast C, and water (also retarder). Seven-inch slump grout.

III.-BUILDINGS - MACHINERY FOUNDATIONS

GROUTING PROGRAM FOR PILE REPAIRS, PORTUARIA AUTOMATA, ACAJUTLA, EL SALVADOR — C, P

Annett, S.R.

American Concrete Institute Journal, vol.69, no.1, p.55-60, January 1972.

An automated pier at Acajutla, El Salvador was founded on piles sunk into volcanic tuff which is the rock native to the area. The final load testing program resulted in unacceptable settlement of certain piles. Water pressure testing following the drilling and coring program indicated that some grout collars between the piles and the volcanic tuff had been broken by the settlement. Remedial procedures consisted of removal of segregated sand and cement from within the piles and replacement with cement grout, or stabilization of loose material at the base of the piles with chemical grout and resealing of grout collars with a combination of cement and chemical grout where water pressure tests indicated defects.

PRESSURE GROUT PILES SUPPORT 230-KV TOWERS IN BOGGY SOIL — P

Aslaksen, G.

Power Engineering, vol.68, no.1, p.47-48, January 1964.

Installation of 40 Mueller-Verpresster piles and determination of pile suitability, and advantage for transmission tower support.

CEMENT GROUT STABILIZES FOUNDATION SITE — P

Batista, Odalis, and Colle, E.R.

Foundation Facts, vol.10, no.1, p.9-12, 1974.

To create a barrier around the area, the two outside rows of holes were drilled and grouted using the established limitations of pressure and quantities until the entire area was sealed off. After the area had been sealed off, the interior holes were drilled and grouted following the established procedure.

BEARING-WALL APARTMENT RISES 17 STORIES IN DENVER — P

Engineering News-Record, vol.177, no.5, p.26-27, August 4, 1966.

Grout pumped to fill bearing wall cavities.

LONG SPAN PRESTRESSED CONCRETE FOLDED PLATE P

Brough, J.C., and Stephens, B.H.

American Society of Civil Engineers, Journal of the Structural Division, vol.86, no.ST10, p.87-108, October 1960, Paper 2630.

The design and construction of long span prestressed concrete folded plate structures are presented. The economics of such design is indicated by including actual construction of four roof structures. A simplified design procedure is outlined and a typical case presented. Field experience with construction methods utilized and recommendations for field inspections are included based on the authors' observations. Grouting of the tendons was accomplished on each job by means of different types of grout equipment. The "Moyno" pump for the pumping of the portland cement grout was very efficient and positive in its action, whereas other types of pumps became inoperative when speed was most necessary.

FOUNDATION REPAIR P

Brown, R.W., Prager, M., and Jansen, J.

Concrete Construction, vol.16, no.7, p.283-285, July 1971, no.8, p.327-328, August 1971.

The success of any concrete foundation repair job depends upon the ability of the contractor who does the job. If properly executed, foundation repair can almost always be considered permanent. These conclusions are drawn from data collected during a 4 1/2-year period from some 380 residential foundation repair jobs in the Dallas, Texas, area. The data indicates that proper foundation repair techniques will always be successful provided the contractor understands the chemical and physical behavior of the local soil constituents and exhibits reasonable perseverance. The Dallas test program involved two types of foundations: pier and beam, and slab on grade. All slab foundations were leveled by controlled pressure injection of either a soil-lime cement or a soil-cement grout beneath the slab. A side benefit of this technique is soil stabilization. In critical areas the lime and/or cement content of the grout can be increased and the methods altered to provide deeper soil penetration and treatment. The data from the Dallas study established that foundation problems can be permanently corrected. The remedial techniques used in this study have been employed with success over a wide area covering most of Texas, and parts of Louisiana, Oklahoma, and Arkansas.

PRESSURE GROUTING STABILIZES FOUNDATION P

Buss, R.E.

American Railway Engineer Association Bulletin, vol.65, no.584, p.484-489, February 1964.
This article discusses the use of portland cement pressure grouting in a foundation problem at Centralia, Ill. A compressor foundation was transmitting vibrations by sliding back and forth on a gelatinous layer of soil. The purpose of the pressure grouting was to solidify the jelly-like layer by replacing the water with a portland-cement grout, and thereby produce a stable base capable of damping the vibrations. Seventy to eighty percent of the vibration was eliminated by use of the grout.

NEUE TECHNIK ZUR HERSTELLUNG DUNNER HORIZONTALER INJEKTION C
(A NEW TECHNIQUE FOR THE MAKING OF THIN HORIZONTAL INJECTION BASES)

Buttner, J.H.

Bautechnik, vol.51, no.2, p.62-65, February 1974.
With deep and extensive excavations for buildings, the lowering of the soil water is an important problem. Extensive lowering can result in severe damage to buildings in the immediate vicinity. With modern grouting techniques it is possible to create horizontal sealing courses, by means of silica gels, by means of which the permeability of a middle sand can be reduced to a fraction of its original value. In German.

CABLE DUCT GROUTING IN P. C. MEMBERS P

Civil Engineering and Public Works Review, vol.57, p.471, April 1962.
The Development Committee of the Prestressed Concrete Development Group has recently been considering the problem arising in the grouting of cable ducts in prestressed concrete members, and after reviewing present knowledge and practice, has produced a set of notes for guidance. The two main objectives when grouting require that the whole of the void space within the duct should be completely filled. Filling will be dependent on the production of a grout mix having the desired properties together with efficient equipment for its injection and careful workmanship and supervision on the site.

LIFTING OF A BUILDING BY MEANS OF INJECTIONS IN THE SOIL P

Cambefort, H., and Puglisi, R.

Annales de l'Institut Technique du Batiment et des Travaux Publics, vol.24, no.281, p.25-36, 1941.
Settling of old building due to sinking of piles repaired by making injections under the level of the pile tips.

NOTES ON THE PREPARATION AND GROUTING OF DUCTS IN PRESTRESSED CONCRETE MEMBERS P

Cement and Concrete Association

Wexham Springs, England, 1971.
In the construction of prestressed concrete structural members, the practice of filling the ducts containing the tendons with grout has two main purposes: (a) to prevent corrosion of the steel tendon, (b) to provide an efficient bond between the tendon and the structural member. The durability and the load-carrying capacity of the member are thereby improved. The preparation of the ducts to receive the injection of grout, the materials, mixing and testing of the grout and the correct procedures for injection, must, however, receive special attention if the complete filling of the ducts and the durability of the grout are to be ensured. These notes summarize the recommendations for successful grouting which have been made by a number of international organizations concerned with prestressing.

EXPERIENCE IN FIXING WATER-LADEN SAND BY MEANS OF CARBAMIDE RESIN M

Cernyj, I.P., and Ibragimov, M.N.

Soil Mechanics and Foundation Engineering, no.1, p.51-53, January - February 1969. (Translated from Osnovaniya, Fundamenty i Mekhanika Gruntov, no.1, p.30-32, 1969.)
Successful stabilization of non-uniform subsidence of water-saturated fine sand beneath the rubble foundations of a seventeenth-century cathedral. Subsidence was caused by the construction of a hydro-power plant.

CHEMICAL MEMBRANE SEALS BASEMENT SLAB C

Engineering News-Record, vol.178, no.16, p.36-41, 20 April 1967.
Chemical grout used as a design feature in Malaysian Airways Headquarters at Singapore to form a waterproof membrane under the basement slab. The grout was a mixture of PC and 2 organic monomers that produced a very stiff gel in a polymerization - nonlinking reaction.

COLD WEATHER GROUTING PROBLEM SOLVED C, M

Roads and Streets, vol.112, no.10, p.61, October 1969.
A major cement producing plant was faced with an unusual grouting problem. Shim pads which support the plates for a speed reducer for grinding mill had to be grouted. Accurate placement of these shim pads was most essential. Normally, each of the pads would be set in a standard grout mixture. But because of the low ambient temperature in mid-winter, the grout would freeze before setting. This would destroy the strength of the grout and the accuracy of the set-up. Grouting experts recommended Nordbak, a nonmetallic backing agent developed by Nordberg Manufacturing Company. Nordbak was used to level the shim pads on rough concrete. Setting up was accomplished by preheating the shim pads with a torch and laying them into a pool of Nordbak. Curing time was thirty minutes. Set-up was well within the close tolerances required. A test pad was set up and in two hours bonding was so good that the pads could not be driven or sledged from the concrete with a ten-pound hammer.

CONCRETE COLUMN TREE FRAME CUTS CONSTRUCTION TIME FOR HOTEL P

Engineering News-Record, vol.185, no.10, p.22-23, September 3, 1970.
A framing system of precast concrete structural members and newly patented cast steel connectors cut construction time for a hotel in Honolulu. Consisting basically of concrete H-shapes, the crossbars form spandrel beams, with the uprights forming half a column below each level of precast floor slabs. The grout-filled reinforcing bar connectors help join the stacked column halfway between floors. Lap-spliced reinforcing bars wound with steel wire protrude from the crossbar ends to connect cast-in-place concrete.

CORES PINPOINT FOUNDATION COSTS P

Engineering News-Record, vol.175, p.33, 22 July 1965.
Foundation for St. Louis apartment. Grouting of fissured limestone below bulled caisson through grout pipe set in center of caisson.

GROUTING: THEN, NOW, AND WHERE P

Daly, J.F.

Foundations for Dams, Engineering Foundation Conference, Pacific Grove, California, March 17-21, 1974, p.57-64. New York, American Society of Civil Engineers, 1974.
The writing of specifications for foundation grouting and putting these specifications into practice as formerly done is compared with current practice.

EPOXY ADHESIVE INJECTION TECHNIQUE FILLS CRACKS, UPGRADES CONCRETE FLOOR SLAB M

Plant Engineering, p.142-144, September 1967.
Structural concrete bonding-pressure injecting of epoxy adhesive into cracks in concrete--was used to restore a severely cracked plant floor on the second floor of International Harvester's truck assembly plant in San Leandro, Calif. Structural concrete bonding, using the epoxy crack injection technique, appeared to offer several advantages: lower cost, little, if any interference with plant production, and the repair could be made in only a few weeks.

VIBRATION IN STEAM TURBINES

Fisher, H.A.

Canadian Engineer, vol.31, p.269, October 5, 1916.
Faulty grouting under the paddle blade is another dangerous source of vibration. Proper mixture and mixing of grout is important for no matter how carefully the grout is placed, it will not be satisfactory if it has not been mixed in the right proportions. If a mixture contains too much cement, it will shrink in setting, while one too lean will crumble.

FOUNDATIONS AND OTHER CONSTRUCTION BELOW GROUND M

Concrete and Constructional Engineering, vol.60, no.6, p.225-231, June 1965.

The application of the method of constructing retaining walls and similar work by processes utilizing bentonite slurry is becoming more common. Some examples which are given include basement walls for city buildings, a shaft 50 feet deep, retaining walls for a tunnel, cylinder foundations, piles, and piles constructed by the bentonite process. In constructing diaphragm retaining walls by the bentonite process, bentonite slurry is deposited in the trench as the excavation proceeds providing support for the earth sides of the trench without the aid of timbering or sheet-piling. A modified form of bentonite was used in the sinking of a shaft through fine silty running sand where ordinary methods of grouting had proved unsuccessful. Load-bearing cast-in situ piles of various shapes are now being constructed by the ICOS bentonite process. Because of the method of construction, piles of almost any shape are practicable.

A NEW FORM OF BORED PILE C

Glossop, R., and Greeves, I.S.

Concrete and Constructional Engineering, vol.41, no.12, p.344-351, December 1946.
This article compares driven piles with bored piles and the use of silicate injections to seal the ground beneath the piles.

GROUTING AS A MEANS OF PREVENTING SETTLING OF BUILDING IN SINKING ADJACENT FOUNDATIONS

Engineering and Contracting, p.593, May 29, 1912.

GROUTING OF PRESTRESSED CONCRETE P

Concrete and Constructional Engineering, vol.57, no.5, p.177-179, May 1962.
Editorial notes. Most engineers agree on what is wanted of a good grout and of the equipment for efficiently mixing and injecting the concrete grouts, but all are not agreed on how to attain these ends. What is less understandable, are the divergencies of practices and opinions among engineers in temperate climates, and these differences are most pronounced in relation to the question of whether or not an admixture should be incorporated in the grout. Admixtures may be used as set-retarders, as anti-freezing measures, as plasticisers, or as expanding agents. The primary object of injecting grout into the ducts containing the tendons is to protect the steel from corrosion. If the grouting is efficient and produces a bond between the tendon and the duct, the ultimate resistance of the prestressed concrete member is increased. The requirements of a good cement grout include sufficient fluidity to ensure that the duct is

completely filled, absence of shrinking and bleeding during setting and hardening, durability, density, sufficient tensile strength to ensure that the tendons in the duct and the concrete around the duct act together when the member is subjugated subsequently to strain, and if need be, resistance to freezing.

GROUTING SUBBALLAST FOR TRACK BASES P

Chicago, Ill., Portland Cement Association, Structural and Railways Bureau, Concrete Information, ST 49-2, 1945.
Discusses the techniques of grouting subballast including grouting material, equipment, and curing time required.

FOUNDATION ENGINEERING P

Hammond, Rolt

New York, Philosophical Library, 1956. 191p.
Examples of repairing bridge piers, ocean breakwaters, and church foundations with conventional grouting methods.

GROUTING UNDER HEAVY MACHINERY

Heron, D.H.

Power, vol.43, p.370, March 14, 1916.

SPECIFICATIONS AND SELECTION OF MATERIALS FOR MASONRY MORTARS AND GROUTS P

Isberner, A.W.

Portland Cement Association, Research and Development Bulletin RD024.01M, 1974.
The role of the grout in masonry construction is to join the individual masonry units with the reinforcing steel within the wall. In balancing the high tensile strength of steel with the compressive strength of the masonry unit, the grout improves the resistance of the masonry structure to loads, either directly or by transfer of stresses. Since grout is a cementitious material with composition similar to masonry mortars but with a different role, it performs similarly and yet differently than mortar. When grouting begins, the fluid grout enters the core, cavity or collar joint and immediately fills the

volume available. After placement, grout vibration and revibration are recommended to obtain a denser grout. During the entire period of grout mixing, pumping, placing, settling, and water loss, the cement in the grout undergoes hydration. In addition to accomplishing its primary mission of joining the masonry unit and steel, the grout contributes to the further curing and strength development of the masonry mortar. Existing specifications within the ASTM standards cover both fine and coarse grouts for reinforced masonry. The selection of a particular grout would be made on the basis of cement content of grout and the minimum horizontal dimension of the space to be grouted. Grout for reinforced masonry should be proportioned in accordance with existing specifications or local codes. In addition, they should be laboratory tested to ensure conformance with the property limits specified. Field tests of grout prisms or masonry assemblages should be used to establish the quality control and environmental influences on the grout; i.e., these test results should be analyzed with consideration of the grouting operation, exposure, and ambient conditions.

GROUND CEMENT FOR GROUTING THE ROCK IN THE BASEMENT P

Jansta, F.

Vodni Hospodarstvi (Prague), vol.22, no.4, Series A, p.91-96, 1972.
Describes technology of machinery and grinding of wet cement with fly ash admixture which tests indicated should be injected before grouting. Comparisons of water pressure tests with ground and normal cements showed a greater advantage for ground cement in grouting a jointed rock.

CONSOLIDATION GROUTING AT CORTONWOOD COLLIERY P

Kaye, R.D.

Colliery Guardian, vol.206, no.5324, p.534-535, 2 May 1963.
Stabilization of ground below headgear abutments and consolidation of hoisting engine foundation at British mine; injection holes were drilled into ground about 2 ft away from abutments. Neat cement was used for fine fissures; portland cement was used when sulfates were encountered.

ENSURING SUPPORT FOR 16-STOREY BLOCK BY GROUTING OLD MINE WORKINGS P

Kaye, R.D., and Woolley, E.R.

Civil Engineering (London), vol.58, no.695, p.1006, August 1963.
Special grouting work in apartment buildings; cement-sand grout was fed down series of closely spread holes to form dam and enclosed area was filled by gravity feed through grid of boreholes.

WATERPROOFING EXPOSED MASONRY WALLS P

Lazarr, T.R.L.

Civil Engineering, vol.33, no.10, p.40-42, October 1963.
Increasing incidence of water penetration through the separation cracks of mortar joints in many buildings forced a search for an efficient and economical means of water-proofing. In this search masonry grouts were investigated to find the answer to the problem. The cost of grouting is about half that of complete repointing. Although masonry grouts have been known and used for many years, most of them have not been perfected to the high quality of performance necessary for this use. Most of them do not meet the requirement of producing evenly filled, smooth and neat joints without changing the appearance of the masonry by discoloration, cloudiness, residue, streaking, staining, and the like. Some do not meet the water test. In the past few years, many types of grouts of different compositions and manufacture have been tried by the author on several buildings with diverse results. To get a comparison of the most promising ones, arrangements were made to install three widely known grouts on test panels under identical conditions and subject them to a water test. The test applications were made by very well-known contractors.

CONSOLIDATION GROUTING CONTROLLED BY SEISMIC METHODS P

Lebegue, Y.

Annales de l'Institut Technique du Batiment et des Travaux Publics, vol.24, no.279, p.37-52, 1971.
Soil foundation for multistory building was consolidated by injections of cement, sand and fly ash. Difficulties encountered included background noise, possibility that the wall of the intact layer might cause a refraction, and the small quantity injected.

MINE GROUTING TO CONTROL BUILDING SETTLEMENT P

Mansur, C.I., and Skouby, M.C.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.96, no.SM2, p.511-522, March 1970, Paper 7166.
During construction of a new building in Belleville, Illinois, it was noted that a portion of the building was beginning to settle and crack when it was only partially complete. The foundation was investigated and remedial measures were taken, such as filling of the mine with cement grout, slowing the settlement process.

MOUNTING AND GROUTING FOR PUMPS P, M

Meyerson, N.L.

Air Conditioning, Heating and Ventilation, vol.60, no.12, p.39-46, December 1963.
Mounting and grouting procedures for close-coupled and coupled pumps; forms of grouting, grout materials, and metal and gas expansion additives for use in grouts are considered.

BITUMEN BEIM BAU VON WASSERKRAFLANLAGEN M

Moesslang, H.

Bitumen, vol.7, no.1, p.17-21, 1937.
Relates the use of bitumen in construction of hydroelectric power plants; its use as joints and insulations in concrete construction, for surface grouting, etc.

PRESSURE INJECTED FOOTINGS P

Nordlund, R.L.

Conference on Design and Installation of Pile Foundations and Cellular Structures, Proceedings, Lehigh University, Bethlehem, Pa., p.297-308, April 1970.
Describes the construction method of pressure injected footings. Discusses use of pressure injected footings on hard pan or rock. Gives a criterion based on dynamic analysis including factors which have been obtained experimentally, which has been used successfully for many years, for allowable loads in granular soils as well as on rocks.

SECURING OF BUILDINGS WITH IMPAIRED STABILITY

Novak, F.

Inzenyrske Stavby, vol.18, no.10, p.384-390, 1970.
Describes electrical stabilization of the subsoil of a building. A leaning building founded on water-saturated silty sediments was stabilized. Steel tubes were driven into the soil around the building and connected across the line of 40 v D.C. Water glass solution and calcium chloride were alternately poured into the tubes. Due to electro-osmosis, the liquid penetrated into the soil. During the second phase, the electro-osmotic injection was supplemented by grouting under a pressure of 6 atm.

HOW TO DESIGN STABLE COMPRESSOR FOUNDATIONS

Novosad, T.L.

Oil and Gas Journal, P.129-132, March 11, 1957.
Study of soil mechanics for prevention of foundation failure due to excessive vibrations; application of principles of soil dynamics.

NOUVEAU PROCEDE DE REMISE A NIVEAU DE BATIMENTS AFFAISSES AU MOYEN D'INJECTIONS DE CIMENT (NEW METHOD OF COMPENSATING SETTLEMENT OF BUILDINGS BY INJECTIONS OF CEMENT GROUT) P

Pleithner, M., and Bernatzik, W.

International Conference on Soil Mechanics and Foundation Engineering, 3rd, Zurich, 1953, Proceedings, vol.1, p.450-453.
Use of grout injections to compensate for settlements illustrated by two case histories. In French.

FOUNDATIONS ON FISSURED LIMESTONE - HOW THEY WERE SELECTED P

Reitz, H.M.

Civil Engineering, vol.35, no.9, p.52-55, September 1965.
Grouting of foundation rock under piling for foundation strengthening. Discusses the use of grouting to fill the voids with a constant-volume permanent material to immobilize the limestone and increase the ability of the rock mass to support loads. Fissures in the limestone were cleaned or filled by inwashed cohesionless soils. High velocity water jets then washed the fissures, and the voids were grouted with a portland cement mix under high pressure.

RESTORATION OF OLD BUILDING P

Engineering and Contracting, vol.44, p.16, October 20, 1915.
Many condemned buildings saved and weak structures made sound by grouting. Method of applying cement grout under pressure.

CURRENT THOUGHTS ON GROUTING P

Rhodes, B.

Dock & Harbor Authority, vol.43, no.508, p.312-314, February 1963.
Two objectives of grouting a post tensioned duct are to provide a protection against corrosion of the prestressing tendon and to provide efficient bond between tendon and concrete in order to control cracking and increase the ultimate moment of the member. There are two distinct schools of thought as to whether expanding agents should be used in the grout, but it does appear fairly logical to at least reduce or minimize the effect of shrinkage in the duct. It is essential that a fully colloidal mix is produced in the mixer, otherwise trouble will be experienced in pumping, and bad grouting with sedimentation will occur. The use of metal sheathing is recommended, as it greatly reduces the problem of absorption of the grout into the concrete during pumping, and also assists the flow. Before grouting, the ducts must be flushed with water in order to remove any loose scale or dirt which has accumulated inside the duct. Only high quality of metal sheathing should be used for post-tensioned concrete work. Both the United States and United Kingdom recommendations agree that high pressures are essential for good grouting. All grout tests are somewhat negative in nature but can be used as controls to determine the quality of the grout, and whether the ducts are completely filled.

HOW TO USE THE NEW PLASTIC GROUTS M

Rowan, R.L.

Pipe Line Industry, vol.14, no.6, p.61-64, June 1961.
The use of resin aggregate grout in gas compressor station is discussed.

FOUNDATION TREATMENT P

Schmidt, L.A.

American Water Works Association Journal, vol.38, no.10, p.1170-1178, October 1946.
Foundation exploration and treatment: Cement grouting in rock, stage and step grouting, cement grout in asphalt grouting, and other foundation treatment.

CEMENT AND CLAY GROUTING OF FOUNDATIONS: PRESENT STATUS OF PRESSURE GROUTING FOUNDATIONS P

Simonds, A.W.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.84, no.SM1, 11p., February 1958, Paper 1544.
Present day use of pressure grouting; examples of successful grouting proved by cores from foundations with cracks and seams bonded by cement grout.

IN REGROUTING CYLINDER FOUNDATIONS USE OF SULFUR WAS NARROWLY AVERTED

Sinback, F.C.

Coal Age, vol.21, p.529, March 30, 1922.

SLURRY INJECTIONS SEAL UNSTABLE SOIL C

Smith, M.L.

Construction Methods and Equipment, vol.51, no.4, p.106-108, 111, April 1969.
Hydrated lime slurry injected into expansive clays under high pressure creates a moisture barrier that controls soil movement and prevents cracks in building foundations and floor slabs. Largest single treatment job was a 200,000-sq-ft site for an apartment complex.

SOME INDUSTRIAL APPLICATIONS OF EPOXY-RESINS, PART 3: GROUTING-IN HEAVY MACHINE TOOLS M

Machinery and Production Engineering, vol.122, p.50-52, 10 January 1973.
Basically there are two methods of using the epoxy-resin. It can either be applied as a pourable mix (similar to the method used for grouting-in with mortar), or the spaces beneath the base of the machine tool can be filled using a tamping mix. When grouting-in with a pourable mix, the resin and the appropriate quantity of hardener are mixed thoroughly, and the resultant mixture is poured into the space between the metal support pads and the main foundations.

LEANING TOWER OF PISA P

Spencer, C.B.

Engineering News-Record, vol.150, no.14, p.40-41, April 2, 1953.
Suggestions on what might have to be done on famous tower including grouting methods.

SYMPOSIUM ON CEMENT AND CLAY GROUTING OF FOUNDATIONS P

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.84, no.SM1, February 1958, 156p., Paper nos. 1544-1552.
Contains nine papers on grouting of foundations.

SOME NOTES ON GROUTING OF MACHINES P

Tolbin, J.M.

Southern Power and Industry, vol.58, p.69-70, August 1940.
Grouting of machinery foundation on base plates including alignment and leveling.

EXPENDABLE LIFTING JACK EASES MACHINE SETTING P

Torry, F.W.

Engineer, vol.228, p.32-33, 26 June 1969.
Discusses a method for setting electric generators and turbines on their foundations by grouting with a standard sand-cement mix of grouting in which a non-shrink additive is included. Grout placed in a pressure vessel is expelled by a compressed air supply through a clear PVC tube permitting good observation of the flow. The level of the grout in the vessel is never allowed to get below one quarter full in order to avoid blow through of air. The sealing plates must be held down to the block surface to prevent their lifting during grouting.

SOME NOTES ON GROUTING OF MACHINES

Totten, J.M.

Southern Power and Industry, vol.58, no.8, p.69-70, August 1940.
Grouting of machinery foundation or base plates including alignment and leveling.

UNDERPINNING BY CHEMICAL CONSOLIDATION C, P

Civil Engineering and Public Works Review, vol.62, no.731, p.645, June 1967.
Clay/cement grout used by Cementation Ltd. to underpin a building foundation adjacent to a construction site. Cementation's own TDM chemical grout will also be used. Very brief article.

VENTURA CITY HALL RESTORATION C

Warner, James

American Society of Civil Engineers, Journal of the Construction Division, vol.102, no.CO1, p.119-130, March 1976, Paper 11970.
Describes the modernization of a concrete frame unreinforced masonry filler wall constructed in 1912. A portion of the existing masonry was removed and replaced with reinforced gunite followed by injection of an expanding epoxy-ceramic foam structural adhesive into the remaining masonry section resulting in an absolute bond between the new construction and existing elements.

PRESTRESSING SYSTEM FOR H.B. ROBINSON NUCLEAR PLANT P

Wern, A.H., Schupack, M., and Larson, W.

American Society of Civil Engineers, Journal of the Power Division, vol.97, no.PO2, p.539-566, March 1971, Paper 7992.
Examines the vertical prestressing steel elements. Their purpose, design details, testing, fabrication, erection, and final stressing and grouting of the vertical tendons for the H.B. Robinson containment structure were evolved using existing hardware in new configurations. They were designed for almost complete shop assembly with a minimum of field labor required and were successfully grouted with portland cement grout, for final and permanent corrosion protection, utilizing a specially formulated grout mix. The Sika grouting admixture Intracrete, which produces nitrogen gas as an expansion agent, was selected as the basic grout additive. This additive was modified to include a gelling agent. Laboratory tests showed consistently the virtual elimination of sedimentation. Based on the successful laboratory tests, no further approach was studied and field tests were performed.

MAT FOUNDATION AND PRELOAD FILL, VA HOSPITAL, TAMPA P

Wheeless, L.D., and Sowers, G.F.

Specialty Conference on Performance of Earth and Earth-Supported Structures, Lafayette, Ind., Purdue University, June 11-14, 1972,

Proceedings, vol.1, part 2, p.939-951. New York, American Society of Civil Engineers, 1972.
During foundation construction, the limestone surface was sealed by cap grouting. In this process a cement-bentonite-sand grout is pumped at low pressure into the formation both above and below the rock surface, plugging both open channels and those that are filled with soft clay.

FOUNDATIONS, STATE-OF-ART REPORT 4

White, E.E.

International Conference on Planning and Design of Tall Buildings, August 21-26, 1972, Proceedings, p.715. New York, American Society of Civil Engineers, 1972.

TIEBACKS FOR BANK OF AMERICA BUILDING FOUNDATION WALL

Wosser, T.D., and Darragh, R.D.

Civil Engineering, vol.40, no.3, p.65-67, March 1970.
Discusses tiebacks used in basement of San Francisco's Bank of America Building, which is 60 feet deep. The prestressed steel rods of the tiebacks are anchored in grout placed only beyond the assumed failure plane.

RESTORATION WORK OF NIRGATA J.N.R. HOSPITAL P

Yokoyama, Genjiroo

Soil and Foundation (Japanese Society of Soil Mechanics and Foundation Engineering), vol.6, no.2, p.78-83, March 1966.
Clay-cement grout injected into soil below entire foundation slab to stabilize soil. Grout injected up to 7 meters deep from 1650 grouting holes through slab.

RECENT DEVELOPMENTS IN GROUTING FOR DEEP MINES P

Ackenheil, A.C., and Dougherty, M.T.

American Society of Civil Engineers, Annual Meeting and National Meeting on Structural Engineering, Pittsburg, Pa., September 30 - October 4, 1968, Preprint 727.
Neat slurry or FA-cement grouts used to grout fine fissures and relatively small voids. With voids 1" to 6" it is usually economical to replace some cement or FA with added bulk material. Can use both sand and gravel depending on size of the void openings. Preplaced aggregate concrete when injected with cement grout to which fly ash is added is reported to be superior to grout without fly ash with respect to compression, tensile, flexural, and bond strength; modulus of rupture and elasticity; drying and shrinkage; permeability; resistance to weathering; resistance to acids, alkalines and sulfates.

BITUMEN ALS DICHTUNGSMITTED IM BAU VON FABRIKANLAGEN M

Adloff, K.

Bitumen, vol.6, no.16, p.226-228, December 1938.
Asphalt as grouting and insulating material in construction of industrial plants with special reference to its use in foundations for plant and machinery.

CONCRETE GUNITING PRACTICES AT BOLIDEN P

Almgren, G., and Ullerstam, A.

Canadian Mining Journal, vol.86, no.8, p.90-92, August 1965.
Concreting as method of rock support as used at mines of Boliden Co.; brief description of equipment, organization, and methods used, together with costs and performance.

CHEMICAL CONSOLIDATION IN A MIXED FACE TUNNEL

Anderson, E.R., and McCusker, T.G.

North American Rapid Excavation and Tunneling Conference, Chicago, 1972, vol.1, p.315-330.

CHEMICAL GROUT CONTROLS HAZARDOUS INFILTRATION C

Antonino, R.A.

World Construction, vol.24, August 1971.
Chemical grouting to seal off a 1.22 m interceptor from petrochemicals seeping into the ground from a nearby oil refinery. The seepage is a safety hazard. Philadelphia, Pa. work performed by Soil Tech, a department of Raymond International. 300 m of line to be grouted around. Chemical grout used because of (a) low viscosity, and (b) controlled gel time. Terranier C manufactured by ITT Rayonier was the grout used. It was chosen because of its resistance to deterioration by petro-chemical substances and its relatively low cost. Mixture was Terranier C, Formaldehyde, and sodium bichromate. Positive displacement pumps (2) used. Packers used on occasion designed to fit inside the pipe and straddle the joint. 25 minutes gel time was used. Large voids were encountered and these are being filled with a sanded cement grout.

GROUTING LEAKS IN THE WASHINGTON STREET TUNNEL UNDER CHICAGO RIVER

Artingstall, William

Engineering News, vol.69, no.2, p.63, January 11, 1912.
Discusses waterproofing the streetcar tunnel on Washington Street.

ASPHALT GROUTING USED IN SHAFT SINKING M

Engineering News-Record, vol.102, no.10, p.375, March 7, 1929.
Asphalt grouting used in sinking a 20-ft salt-mine shaft through water bearing gypsum to depth of 250 ft. Shaft fully lined with concrete.

RESIN SEALING OF WATER-BEARING BEDS IN RUHR SHAFT M

Au, E.

Mining Magazine, vol.110, no.3, p.171, 173, 175, March 1964.
Epoxy resin was used to seal off vulnerable water-bearing rocks in turonian series in shaft in eastern part of Ruhr; combination of pressure grouting with C_3A-free cement and Epikote resin compound should provide thoroughly economic and effective means of sealing shafts.

POVYSENIE USTOJEIVOSTI GORNYCH VYRABOTOK SPOSOBOM UPROCNENIJA OKRUZAJUSCICH POROD (INCREASING THE STABILITY OF MINE OPENINGS BY GROUTING THE SURROUNDING ROCKS) P

Bardus, A.

Sachtnoe Stroitel'stvo, vol.16, no.8, p.18-19, 1972.
In some collieries of the West Donets Basin, USSR, which were sunk in unstable carboniferous rocks, supports often failed due to rock pressures. Grouting was carried out under a pressure of 2-3 kp/cm^2. In the strengthened sections, the problems were almost totally avoided. In Russian.

BENTONITE TUNNELING MACHINE M

Bartlett, J.V., Biggart, A.R., and Triggs, R.L.

Institution of Civil Engineers (London), Proceedings, vol.54, part I, p.605-624, November 1973.
Describes a new method of driving tunnels through granular soils above or below the water table using a mechanical tunneling machine within which the face is supported by a thixotropic slurry. The development of the system and the results of the experimental tunnel drive at New Cross are reported. The methods of organizing and financing development work of this nature are discussed. Slurry trench walls were sunk to form a hexagonal shaft. After completing the walls a long box was consolidated outside the section of wall in which the tunnel eye was to be formed. The initial drive left a protective wall of consolidated ground ahead of the face with the permanent lining grouted and the first ring doweled through the grout holes into the shaft walls. The final conventional excavation took in the last row of tubes-a-manchette leaving a thin wall of consolidated ground. The machine itself was converted to its bentonite role and a thick bentonite grout was pumped around the outside of the machine body.

SOFT GROUND TUNNELLING FOR THE TORONTO SUBWAY P

Bartlett, J.V., Noskiewicz, T.M., and Ramsay, J.A.

Institution of Civil Engineers (London), Proceedings, vol.32, p.53-75, September 1965, Paper 6859.
Describes grouting of tunnel linings with neat portland cement; block cement tried but grout built up on metal liners, changed to ordinary cement and no trouble encountered.

PROBLEMS OF SHAFT SINKING IN A MICHIGAN SALT MINE

Beasley, N.B.

Mining World, March 1909.

BENTONITE TUNNELLING SHIELD M

Tunnels and Tunnelling, vol.4, no.6, p.519, November-December 1972.
Although the construction industry has been using a thixotropic slurry of bentonite to support trench sides during excavation for many years, its application to tunnelling in soft ground is a new development. An experimental tunnel is being driven in unstable ground at New Cross in the London Borough of Lewisham. It is thought that this all-British development could provide an answer to the particular problems of tunnelling under a congested city where the optimum tunnel alignment might lie in water bearing sands and gravels. The tunnelling is through bad ground, sand, and gravels, and is said to be costing significantly less than it would have if done by conventional methods. The machine and method also eliminated the use of compressed air which can cause bone necrosis in tunnel miners. Furthermore, the risk of subsidence is reduced to nil. As a tunnelling machine it is similar to other excavator shields designed for wet ground tunnelling except that the cutters revolve in a sealed chamber which is filled with a thixotropic slurry of bentonite clay under pressure. Bentonite forms a skin on the tunnel face and seals it, so preventing collapse. One tunnel ring at a time is built up from cast iron segments in the tail of the machine, the machine pushing itself forward by jacking against the completed ring. Two methods are used to prevent the passage of the slurry from the face along the outside of the shield skin and into the tunnel behind the tail. A thick bentonite grout is injected through ports around the skin and a barrier is formed between the tail and the completed tunnel lining by means of a circumferential nylon brush seal. The latter may also be applicable to conventional shield tunnelling methods as an alternative to "fluffing up" for containing the cavity grout.

BERGMEKANISKT DISKUSSIONSMOTE (ROCK MECHANICS CONFERENCE)

Stockholm, Royal Swedish Institute for Engineering Research (IVA), Report no.29, 1970.
Proceedings of this conference are made up of 20 technical papers One of the subjects discussed is the results of tests on the penetration of grouting materials into thin cracks to prevent tunnel leakage. In Swedish, with English summaries.

MESURE DES MODULES ELASTIQUES ET APPLICATION AU CALCUL DES GALERIES EN CHARGE (MEASUREMENTS OF MODULI OF ELASTICITY AND THEIR APPLICATION TO THE DESIGN OF PRESSURE TUNNELS) P

Bernard, P.

International Conference on Soil Mechanics and Foundation Engineering, 3rd, Zurich, 1953, Proceedings, vol.2, p.145-156.
The writer describes tests which were carried out on many types of rock encountered in drilling a tunnel. The cement grouting tests (measurement of stresses in lining during and after injection, determination of strains under loaded galleries and pack tests before and after grouting) show that the lining contracts during the grouting process to a great extent permanently, the strains under loadings are reduced, and are equalized in the various planes, and the deformations obtained in the first tests were almost eliminated by grouting. In French with brief English summary.

BIG POTENTIAL FOR NEW PLASTIC PUTTY

South African Mining and Engineering Journal, vol.72, no.3567, p.1399, June 16, 1961.

EXPENSIVE REPAIRS TO AN 8-INCH WATER MAIN 40 FEET UNDER WATER P

Blackburn, N.T.

Engineering News, vol.72, no.4, p.201-202, July 23, 1914.
Discusses repair of leaking joints by grouting.

BLACKWALL TUNNEL DUPLICATION; GROUTING OF SAND AND GRAVEL C

Cement, Lime and Gravel, vol.37, p.27-28, January 1962.
Because of the permeable strata underlying the Thames it is necessary to use compressed air during the driving of the main tunnel. To minimize loss of air through the upper portion of the tunnel and an egress of water in the lower portion, a grouted annulus will be constructed in the sand and gravel beds before the tunnel is driven. This annulus will be formed by injecting clay and chemical grouts into the ground through special injection rods driven from two 7-ft.-diameter pilot tunnels.

SAN MANUEL LOWERS COSTS BY GROUTING BAD GROUND P

Bogert, J.R.

Mining World, vol.23, p.22-25, September 1961.

Unique method of pressure grouting is used to stabilize highly fractured or broken ground at the San Manuel Mine in Arizona. This is one of the first mines in the United States to use grout extensively for strengthening and stabilizing drifts, shafts, and other underground workings.

TUNNEL INTERFACE CROSSING SOLVED BY SPECIALIZED CONSOLIDATION C

Brain, M.G.

Ground Engineering, vol.5, no.5, p.14-21, 1972.
Extensive grouting was required during the driving of the cooling water tunnel for the outlet system for the Hunterston Nuclear Power Station in Scotland. A strata of sandy clay, gravel and small boulders ran diagonally across the axis of the tunnel. The clay matrix content suggested that this type of ground could be regarded as impervious from the practical aspect of tunneling operations, but during the tunnel excavation two roof collapses occurred, followed by ingress of sand and water. The original problem was to consolidate a section of 12.2 m effecting a transfer from rock into clay. An extended length of 45 m was eventually grouted using chemicals.

DETECTION AND SEALING OF LEAKS IN SEWERS C

Brunton, B.W.

Canadian Municipal Utilities, vol.101, no.12, p.22-23, December 1963.
The use of a non-chemical grouting method for sewer joints is discussed. Some of the advantages of the method are: (a) It may be successfully used in sewers which are already in operation; (b) It eliminates the need for costly pavement cuts; (c) It can eliminate costly sheeting or dewatering operations. Some of the limitations are: (a) It is uneconomical where joints are two or more inches apart or where shallow excavations can be made in stable soil; (b) It does not offer a solution to the problems of cracked or broken pipes, or to ponding areas in sewer lines.

LONGEVITY OF SEWER GROUT UNDER SEVERE CONDITIONS C

Calhoun, T.P.

Public Works, vol.106, no.10, p.80, October 1975.
A discussion of the permanence of chemical grout repairs made on leaky sewer systems to prevent infiltration of ground water.

FLOODING AND RECOVERY OF ASTORIA TUNNEL

Carpenter, H.

Engineering News, vol.74, no.15, p.673-678, October 7, 1915; vol.74, no.16, p.736-741, October 14, 1915.
Describes the use of grout sealing to control leak in Astoria Tunnel. Leak was grouted through a 22-ft drill hole from the Astoria bulkhead.

CEMENTING OPERATIONS

Oil and Gas Journal, vol.49, p.182, 184, and 187, October 5, 1950.
Contains description of grouting casing in oil wells; includes equipment and method.

CHEMICAL ADDITIVES CUT GROUTING COSTS C

Engineering Mining Journal, vol.160, p.28, October 1969.
A 1 to 1 sand cement with a 50% solution of Sika No.2 and No.4 additive was used. Additive controlled setting time of grout. The grout was placed in a six-inch casing to which a 90 psi air supply was attached; the grout was forced into surrounding rock.

DRIVING A TUNNEL IN DIFFICULT ROCK UNDER HIGH HYDROSTATIC PRESSURE P

Colombet, G., and Guillen, I.A.

International Association of Engineering Geologists, International Congress, First, Paris, 1970, Proceedings, vol.2, p.1185-1196.
Surroundings and the head of each tunnel section of a tunnel driven through the Sainte-Baume mountain in France were grouted with cement injections before starting the excavation. Better consolidation was reached with a mixture of cement and silicate grout.

CONCRETE RETAINING WALL SPACES CUT FOR SUBWAY UNDERCROSSING P

Engineering Record, vol.72, no.21, p.642, November 20, 1915.
Grouting with a wire.

CONSTRUCTION UNDERWATER: DIVERS JOIN CONSTRUCTION TEAM P

Construction Methods and Equipment, vol.48, no.12, p.56-59, December 1966.
Divers perform grouting with plastic bags and a knife. Plastic-lined burlap bags of dry concrete mix placed in position then slashed

several times with a knife, allowing water to enter and start the hydration process. High viscosity grout also pumped into area of concern.

CONTRACTOR CUTS 2-MILE TUNNEL WITH 80-FT-LONG GANGED FORMS M

Engineering News-Record, vol.172, no.25, p.82-83, June 18, 1964.
Construction of 2-mile-long concrete tunnel for Stanford University's linear accelerator requires special techniques, including elaborate epoxy grouting of joints. Properly applied, the epoxy forms a stronger joint than the concrete itself. By resisting the closing of construction joints, resulting in the expansion of concrete in the high temperatures produced by the energy dissipated inside the accelerator, it enhances the structural integrity of the tunnel.

PRESSURIZED GROUTING OF DEEP DIAMOND DRILL HOLE BY BROKEN HILL SOUTH, LTD. P

Copley, J.D., and Jones, I.C.

Australasian Institute of Mining and Metallurgy, Proceedings, no.220, p.65-67, December 1966.
Problem of sealing a fluid sericite zone at hole depth of 4000 ft. was overcome by using a composite non-return valve plug and rod assembly which enabled cement to be forced under pressure into the zone.

TUNNEL SHIELDS AND THE USE OF COMPRESSED AIR IN SUBAQUEOUS WORKS C

Copperthwaite, W.C.

London, Constable & Co., 1906.

CHEMICAL SEAL STOPS SEWER INFILTRATION C

Dahlmeyer, F.D.

Public Works, vol.93, no.11, p.91-92, November 1962.
Use of the "Sealetryn" process employed by the Penetryn System, of West Hollywood, Florida to combat infiltration solved the problem of low pressure infiltration into some of the sanitary sewer lines located along a bay front in Hollywood, Florida. Prior to the treatment operations, a series of three tests--infiltration, chlorides, exfiltration--was performed to establish the amounts of infiltration flowing into the section. Objectives of the treatment process were to stabilize and waterproof the soil surrounding the sewer line by introduction of a chemical grout which, after exposure to a catalyst solution, forms a stiff gel that is impermeable to water. Selection

of the three materials used was based on the local soil conditions, the depth of the line, and the amount of infiltration recorded during the preliminary tests. After the treatment procedures had been completed, tests identical to those run prior to the sealing work were conducted to determine the effectiveness of the treatment. The cost of eliminating infiltration with this method varies in accordance with the pipe size, local soil conditions, size of the contract, and other related factors.

AT NORAD CENTER - NEW TECHNIQUES FOR BACKFILLING SHAFTS P

Davenport, J.D., and King, J.C.

Civil Engineering, vol.33, no.10, p.55-57, October 1963.
Cement grouting at Combat Operations Center of the North American Air Defense Command (NORAD) in Colorado. A 3,000 psi cement sand grout suggested two areas, 1,700 cy yd and 1,600 cu yd were to be grouted. Grout batched at a concrete plant in 6-yd batches and hauled 14 miles by concrete truck. Consistency of grout checked by flow cone. Three mix ratios actually used. They were 3:1:4, 2:1:6, 2:1:4 (cement to fly ash to sand.) All mixes contained Master Build as Pozzolith 3R which provided 1 mm of controlled retardation of stiffening at 70 degrees Fahrenheit (and above).

GROUTING MACHINE FOR ASTORIA TUNNEL, NEW YORK CITY

Davies, J.V.

Engineering and Contracting, vol.45, p.470, May 24, 1916.

GROUTING AT A PHILIPPINE GOLD MINE: SUMMARY OF GROUTING METHODS USED AT ANTOMAK MINE

Daws, M.K.

Mining Magazine, vol.114, p.215+, March 1966.

DEEP TUNNEL COMPLETED IN UNSOUND ROCK SOLIDIFIED BY EXTRAORDINARY GROUTING

Engineering Record, p.417, October 2, 1915.
After rush of water and debris flooded one end of Astoria Tunnel fissures were plugged from behind bulkhead at other end.

PRE-GROUTING OF THE DOLOMITE AT NO.4 SHAFT, HARTEBEESTFONTEIN P

De Villiers, G.S.

Association of Mine Managers, South Africa, Papers and Discussions, 1960-61, p.129-139, 1962.

Discusses the pre-grouting operations in treating a serious water hazard in water-bearing dolomites in six phases. The first phase covers the grouting of the collar area itself, which is essential whether pre-grouting is intended or not, and the remaining five phases deal exclusively with the diamond-drilling and pre-grouting operations themselves. It was decided to attempt complete grouting of the dolomite before full-scale sinking was started because there appeared to be sufficient time in which to carry out this operation and it was considered that sinking through a completed pre-grouted plug would result in less residual water than grouting concurrently with sinking. It was decided that the dolomite in each case required eight holes to produce an effective seal. The paper describes how, although actual practice proved to be somewhat more complicated than envisaged, the planned methods were carried out to achieve the most successful results.

DIVIDE TUNNEL: QUITE A LITTLE DIFFICULTY P

Engineering News-Record, vol.181, no.22, p.64-66, 28 November 1968.

Tunnel under Continental Divide in Colorado. High pressure cement grouting from 300 to 1,300 psi. PC mixtures with water/cement ratio ranging from 4:1 to 7:1. Holes grouted to refusal. 2,000 psi used to grout some unconsolidated material. Water pressure and flows reduced as a result of the grouting.

SINKING AND LINING OF SHAFTS

Donaldson, F.

Scientific American, vol.77, p.34, January 17, 1914.

EFFECT OF CHEMICALLY GROUTED COFFERDAM ON WATER FLOW C

Dore, S.M.

American Water Works Association, Journal, vol.58, no.6, p.673-675, June 1966.

The New York City Board of Water Supply is engaged in the construction of the Richmond Water Supply Project. To construct the dual conduit connection of the tunnel, the subsoil foundation of the conduit was stabilized by grouting. One cofferdam proved particularly

troublesome. The contractor decided to replace the wellpoint dewatering system as rapidly as possible. His plan was to grout a curtain wall around the perimeter of the cofferdam. In the first six working days, the contractor injected 50% chemical grout, Formula A. This is a mixture of three chemicals, plus water, that is varied according to soil, temperature and result desired. The chemicals include a modified silicate, an amide, and a chloride. The chloride serves as an accelerator to control the rate of initial setting. The final five wellpoints were pulled without grouting. The grout pumped into them appeared immediately on the surface of the floor in full strength, indicating that the job was completed. After this, the contractor used fifty per cent grout, Formula B, to solidify the base of the cofferdam. This grout is a mixture of a modified silicate, an amide and a portland cement slurry. The chemical grout system does not use an accelerator with cement. The job took 21 working days.

FORMING AND CONCRETING OF SMALL DIAMETER TUNNEL LININGS P

Dowie, J., and Gilmour, P.E.

Consulting Engineer (London), vol.27, February 1965.
Describes grouting of tunnels.

INJECTIONS WITH HIGH PRESSURES IN DEEP MINES P

Du Bois, E.

Grouts and Drilling Muds in Engineering Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, May 1963, ed. by A.D.M. Penman, p.70-74. London, Butterworths, 1963.
High pressure grouting with PC, portland blast furnace slag, and cement and slag.

TRANSPORT EN CONDUITE DE MORTIER POUR INJECTION DE L'AMENAGEMENT LANOUX-HOSPITALET P

Duffault, P., and Schneebeli, G.

Travaux, vol.47, no.340, p.48-54, February 1963.
Pipe transportation of grout mortar for pressure intake tunnel of Lanoux-Hospitalet Scheme. Mortar used in back-grouting intake tunnel of hydroelectric scheme; mortar consisted of three parts of sand to one of cement and was prepared outside tunnel in completely automatic plant; it was then pumped through 1 1/2" diameter pipe over distance which reached as much as three km; rheological properties of mortar, and effect of bentonite addition are discussed. In French.

EAST RIVER TUNNEL SHIELD P

Engineering News, vol.74, no.20, p.952-955, November 11, 1915.
Void spaces filled with gravel. Some distance back of this point a regular 1:1 cement sand grout is placed using grouting holes.

CHEMICAL GROUTING AIDS CANADIAN SHAFT CONTRACTOR C

Easton, A.W.

Canadian Mining Journal, vol.86, no.7, p.43-45, July 1965.
Exploration and development of gold property in Quebec required installation of 88 ft concrete collar in preparation for 600 ft vertical shaft; claim is overlain by fine glacial sand, lower 30 ft of which is water bearing; AM9 chemical grout was selected for grouting system.

EMPINGHAM WORK-START ON SHAFT DRIVING AND GROUTING C

Ground Engineering, vol.5, no.3, p.30, May 1972.
After excavation precast concrete segments are being used to line the shaft and tunnels at Empingham; then a cement grout containing Combex is pumped behind the segments as soon as they have been positioned.

LININGS OF PRESSURE TUNNELS WITH DEEP ROCK GROUTING (OB OBDELKAKH NAPORNYKH TUNNELEI S GLUBOKOI TSEMENTATSIEI PORODY)

Eristov, V.S.

Hydrotechnical Construction, no.7, July 1973. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.7, p.6-12, July 1973.)

RONDOUT PRESSURE TUNNEL OF THE CATSKILL AQUEDUCT, NEW YORK CITY

Flinn, A.D.

Engineering News, vol.65, no.22, p.654-661, June 1, 1911.
Discusses grouting of tunnel in the Catskill Aqueduct between the Ashokan Reservoir and New York City.

A GUIDE TO SLABJACKING P

Florida Department of Transportation

Tallahassee, Florida.
Gives complete directions for slabjacking, including when to

slabjack, when not to slabjack, recommended personnel and equipment, grout mix design, location of holes, leakage or blowouts, and filling voids.

GROUTING ON THE LINE OF THE CATSKILL AQUEDUCT (DISCUSSION OF ASTORIA TUNNEL)

Freeman, M.H.

American Society of Civil Engineers, Transactions, vol.80, p.677-681, 1916.
Brief description of difficulties and variety of ways to meet them.

LEAKY SUBWAY TUNNEL SUCCESSFULLY GROUTED M

Freeman, M.H.

Engineering News-Record, vol.85, no.7, p.314-318, August 12, 1920.
Inflow of more than 150 gpm through broken joints in waterproofing checked by grout injection through pipes tapping the leaking joints.

TV INSPECTION AND CHEMICAL GROUTING OF SANITARY SEWER LINES C

Gandy, B.

Air Force Civil Engineer, vol.12, no.1, p.6-7, February 1971.
Reports measures taken to repair apparent deficiencies of the sewer system for the Wherry Housing at Mather Air Force Base, California. A contract was let to take pictures in approximately 3,000 feet of line with a 3-dimensional camera to get an idea of the condition of the lines. It proved that a problem existed. A thorough investigation was made of the methods of control and repair. The chemical grout method appeared especially promising as it had been used to bar water infiltration into mines and basements, and also as a barrier in leaking earth dams. The method after line cleaning uses a TV camera with a headlight and skids mounted in tandem about three feet ahead of the packer, facing it. As the camera and packer are pulled through the lines the viewer constantly makes a visual check of the interior and records the information. All unusual conditions and all connections are noted. The chemical used is based on a mixture of two organic monomers. The chemicals, before setting, are a solution. The setting time can be controlled from seconds to hours and the chemicals will also allow dilution. After setting, the material resembles a very stiff gelatin and has considerable compressive and tensile strength. The specifications were detailed and provided for base inspectors to be with the camera viewer at all

times and, as the joint grouting was on a unit basis, to have authority to reject or accept the recommendation of the contractor as to the grouting of each joint.

DRILLING AND GROUTING EXPERIENCES IN UNDERGROUND CONSTRUCTION M

Gebhart, L.R.

Paper presented at International Symposium on Protection of Underground Construction Against Water, Bratislava, Czechoslovakia, June 1972, 25p.
Discusses grouting procedures used in 3 different tunneling projects to reduce the flow of water or to stabilize the material.

VENDOME SOLVES WATER CONTROL PROBLEM - GROUTING AND SEAM P

Geoffroy, P.R., and others

Mining Engineering, vol.7, p.1026-1028, November 1955.
Water inflow into a mine shaft channeled through a mud sea. Ten-foot grout holes drilled through the shaft walls; clear water flowed. Sawdust and cement grout injected.

DRIVING AN INCLINED SHAFT USING CHEMICAL SOIL STABILIZATION M

Goncaruk, P.P., Klimenko, J.T., Kagnovic, M.Z., Lauchin, J.A., and Fateev, N.T.

Sachtnoe Stroitel'stvo, vol.14, no.3, p.22-24, 1970.
Chemical stabilization of water-saturated sand by grouting with a synthetic resin with a hardener is described in driving a mining shaft.

USE OF PRESSURE GROUTING TO STABILIZE GROUND IN SAN MANUEL MINE P

Goss, J.W., and Coolbaugh, N.J.

Mining Engineering, vol.13, p.255-261, March 1961.
Extensive use of grouting to strengthen ground around drifts. Comparative cost of grout versus timber.

CONSTRUCTION OF THE SAIONG TUNNEL IN MALAYSIA P

Goss-Chalk, E.M., and Boston, A.G.

Tunnels and Tunneling, vol.2, no.1, p.41-44, January-February 1970.

A portland cement sand grout used to grout tunnel crown at low pressures to fill voids between concrete lining (placed by pneumatic placers) and rock. Approximately 9,700 cu yd grout used. Also, some rock bolts placed with grout. In some cases the grout was accelerated. Tensile tests on bolts 2 hours after installation showed that loads of over 7 tons per bolt could be sustained. The bolts were 6 ft long and 1 inch in diameter (this gives a cross-sectional area for the bolts of 0.79 in.^{2})

MINE SUBSIDENCE AND SUPPORT METHODS IN PITTSBURGH AREA P

Gray, R.E., and Meyers, J.F.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.96, no.SM4, p.1269-1287, July 1970, Paper 7407.
Discusses subsurface stabilization in mines and the use of grout columns in tunnels and shafts.

CHEMICAL GROUT DOES THE JOB C

Griffin, C.W.

Reclamation Era, vol.59, no.1, p.20-23, Winter 1973.
The use of AM-9 grout to repair leaks in a pressure tunnel of an aqueduct water supply system in Colorado.

GROUTING A LEAKY TUNNEL

Engineering Record, vol.11, p.60, January 9, 1915.

GROUTING A LEAKY TUNNEL ON THE PARIS, LYONS, AND MEDITERRANEAN RAILWAY P

Engineering News, vol.56, no.15, p.374-375, October 11, 1906.
Portland cement grout was pumped through holes in the arch of a railroad tunnel to effect the desired waterproofing.

GROUTING A WATER MAIN IN FORTY FEET OF WATER P

Cement Era, vol.12, p.10, October 1914.
Application of portland cement to closure of openings otherwise difficult to reach.

GROUTING OPERATIONS FOR NEW BLACKWALL TUNNEL M

Civil Engineering and Public Works Review, vol.57, no.667, p.204, February 1962.

Blackwall Tunnel Duplication Project will carry the south-bound traffic under the River Thames. Because of permeable strata underlying the river, it is necessary to use compressed air during the driving of the main tunnel. To minimize the loss of air through the upper portion of the tunnel and an ingress of water in the lower portion, a grouted annulus will be constructed in the sand and gravel beds before the tunnel is driven. This annulus will be formed by injecting clay and chemical grouts through special injection rods driven from two pilot tunnels. Clay grouts conditioned with chemicals are used for a major part of the annulus. For the preparation of the grout, a central mixing unit at the surface controlled by only two men can produce 2,000 gallons of clay slurry every ten minutes. Before each batch passes through the supply lines to the injection points in the tunnel, samples of the slurry are tested in the site laboratory and the exact quantities of conditioning chemicals needed to produce the required gelling characteristics are established. The conditioning chemicals are conveyed by a separate line to special injection pumps which deliver the required quantities of each constituent of the grout to a mixing chamber fitted to the head of the injection rods. The working space in the pilot tunnel is so limited and the number and distribution of grouting teams along the tunnel is such that normal communication methods would make it difficult for the engineers to obtain an overall picture and maintain the high degree of control required for this type of work. The Cementation Company has therefore introduced electronic methods of transporting the vital data to a control center on the south side of the river. Nine electric cables transfer the pressures, rate of injection, and quantities of grout injected by each pump.

GROUTING OPERATIONS IN THAMES PILOT TUNNELS

Muck Shifter and Bulk Handler, vol.20, p.210-212, May 1962.

GROUTING STOPS INFILTRATION IN LARGE-DIAMETER STORM DRAINS

Public Works, vol.106, no.9, p.82, September 1975.

Describes the repair method of masonry joints in a sewer system in which a new hydrophilic polymer grouting material was used. Because the grouting material is a low-viscosity liquid which expands up to 10 times, the joint is sealed with a tough, flexible seal within minutes.

GROUTING TO CLOSE LEAKS AND SOLIDIFY ROCK IN TUNNEL EXCAVATION

Engineering and Contracting, vol.44, p.23, December 8, 1915.

GROUTING TO SOLIDIFY FISSURED AND BROKEN ROCK FOR ASTORIA TUNNEL EXCAVATION NEAR NEW YORK CITY C, P

Engineering and Contracting, p.448-449, December 8, 1915. (Abstract of paper by J.V. Davies in American Society of Civil Engineers, Transactions, vol.80, p.594, 1916, giving details and equipment.)

REACTIVE GAS GROUTS AIR DRILLED OIL WELL M

Gulf Oil Corporation

Engineering Mining Journal, vol.160, p.109, November 1959.
The water bearing zone was sealed off by a packer. Oil was pumped into the hole followed by inert nitrogen gas, silicon tetrafluoride, followed by more nitrogen gas. It was then sealed by another packer. Water was pumped into the hole causing the packer to apply pressure to the sealed-off ingredients, forcing the oil into the rock, pushing any water ahead.

GROUND WATER AT TUNNELLING P

Gustafsson, Y., Sund, B., and Lindh, A.

Byggmastaren, vol.49, no.6, p.23-26, 1970.
Water leakage into rock tunnels is frequently the reason for large investments in injection measures. The width of the most affected zone is equal to twice the depth of the tunnel both theoretically and practically. The leakage into a tunnel has been studied under varying conditions by using the analogy between fluid flow and electric current.

FROM THE BOTTOM UP, INNOVATION MEANS A LONG HARD SLOG M

Hammond, Brian

Engineer, vol.236, no.6096, p.50-51, 11 January 1973.
To bring a concept off the drawing board and into production is a full-time job demanding both luck and dedication--and of course an identifiable market. One success story in this line is the bentonite tunnelling shield, a promising breakthrough in civil engineering. It is worth examining the anatomy of its development over the last

nine years from conceptual origin to test operations to illustrate some of the manifold hurdles inventors are forced to jump to get their creation to the winning post. In 1968, John Bartlett, a director and partner of consulting engineers Mott, Hay, and Anderson, approached the National Research Development Corporation. At that stage, a little work had been carried out on a small scale, but the main assets remained an idea, a patent to cover it, and faith that it could be made to work. The prototype tunnelling was ready to go in December 1971 and the test operation has been under way for a year--at the same time providing a useful promotional showpiece for a steady flow of technical and town-planning visitors from abroad. And the exercise has already spun off a respectable number of further patents as experiments and discoveries progress in the working situation. One interesting fringe benefit discovered during operations is that the use of the bentonite slurry provides a perfectly watertight tunnel. The bentonite soaks into the surrounding ground as the machine advances--at a rate of half a meter cut every hour--and gives a perfect seal which may make it possible to eliminate the caulking process.

CONSTRUCTION OF THE BAREGG TUNNEL IN BADEN (SWITZERLAND)

Haubitz, G.

Tiefbau, vol.11, no.1, p.19-20, 1969.
Discusses the use of contact grouts to fill and seal voids during the construction of a road tunnel at Baden.

SQUEEZE CEMENTING

Howard, G.C., and Fast, C.R.

Oil and Gas Journal, vol.48, p.75, 76, and 78, December 1, 1949.
Description of high pressure methods used in oil fields.

GROUTING SOLVES WATER PROBLEM AT KENNECOTT'S DEEP RUTH SHAFT P

Huttl, J.B.

Engineering Mining Journal, vol.154, no.11, p.94-95, November 1953.
Water inflow of 10,000 gpm was brought under control by injection of grout composed of cement, fly ash, and "intrusion aid."

EXPERIMENT OF PRESSURE GROUTING INTO FINE FISSURES M

Ishii, M.

Tokyo, Railway Technical Research Institute, Japanese National

Railways, Quarterly Report, vol.4, no.2, p.24-27, June 1963.
Tests during undersea tunnel construction; use of Johnston's Formulation Test Method for seepage with water injection by grouting pump.

RECENT BRITISH EXPERIENCE ON UNDERGROUND WORK AND ROCK MECHANICS P

Jaeger, C.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, p.167-189.
The techniques of rock mechanics have been built up mainly on the results of tunnelling; the present knowledge of this subject is not satisfactory and many difficulties have been met. This paper describes recent British experience on tunnels, foundations and grouting, the examples covering works with a variety of rock and foundation conditions, both in Britain and overseas. From the results of the tests carried out on the prestressed dam at Allt-na-Lairige, Scotland, the anchorage stress conditions in the rock are analyzed by Boussinesq equations. A study is made of the minimum amount of rock cover required on tunnels and galleries under pressure. Precautions to be observed when using high grouting pressures and limiting conditions for safety are outlined. Finally, an appeal is made to carry out and make available the results of rock tests on a large scale so as to advance present knowledge and establish the science of rock mechanics on a sound basis.

CHEMICAL GROUTING FOR PARIS RAPID TRANSIT TUNNELS C

Janin, J.J., and Sciellour, G.F.L.

American Society of Civil Engineers, Journal of the Construction Division, vol.96, no.CO1, p.61-74, June 1970, Paper 7382.
Two methods of grouting of sands are used: (1) impregnation of sands by means of a diluted silica gel giving a low strength, then partitioning of the impregnated sand by cement grouting under high pressure; and (2) grouting through two closely drilled holes using a pure silicate and a reagent such as calcium chloride (Joosten Process.) The main inconvenience is the required high pressure. The desire to solve this problem has led to development of 2 types of grout material, gels and resins. The use of clay cement, carongel, and phenoplastic resins are described. The development of new injection methods is also discussed.

JAPANESE TACKLE WATER TO DRIVE RECORD TUNNEL C

Engineering News-Record, vol.192, no.14, p.16-17, April 4, 1974.

Japanese contractors are grouting their way through water-laden faults 330 feet below the bed of Tsugaru Strait as they drive the world's longest railway tunnel which will connect the main island of Honshu with Hokkaido. The contractors are boring tunnel tubes from each side of the strait: a pilot tunnel to prove the geology, a service tunnel to get material and equipment in, and muck out of the main tunnel. A grouting procedure was developed that calls for tunnelers to drill two sets of grout holes, 200 ft long and 100 ft long, from the tube head at outward angles. They inject grout into the surrounding area to a depth of about three times the radius of the pilot bore. Then tunnelers drive ahead another 170 feet to start the next round of grouting which is done under a 30-ft-long grouted rock cover. The grout is called water glass, a mixture of silicon, soda, and water, used especially for salt-water applications. It has a longer than usual gel time so it can reach far into the cracks before solidifying.

JET GROUTING - NEW CEMENTATION TECHNIQUE P

South African Mining & Engineering Journal, vol.74, no.3655, p.423-424, February 22, 1963.
Process for production of diaphragms of interlocking columns in sand--most effective in common silty sands. Overcomes many limitations of other methods where sandy soils are concerned. Discusses possible fields of application.

METHODS OF GROUTING IN SHAFT SINKING P

Johnson, R.G.

Engineering and Contracting, vol.60, p.315-316, August 15, 1923.
Injection of cement into the fissures of water-bearing strata.

FACTORS INFLUENCING BOND BETWEEN OIL WELL CEMENT AND FORMATION

Jones, P.H., and Berdine, D.

Petroleum World (Los Angeles), vol.37, no.6, p.26-30, p.32, 34, 42, and p.57-59, June 1940.
Cement channeling and factors influencing bond between set cement and formation were investigated in series of 42 tests using relatively large-scale apparatus; results, presented photographically, show that mud cakes will persist between set cement and permeable formations unless removed by means such as hydrulic jetting, mechanical scraping, or chemical action.

BAU EINES HAUPTSAMMLERS UNTER DEN GLEISANLAGEN DES MUNCHENER HAUPTBAHNHOFES (CONSTRUCTION OF A MAIN SEWER UNDER THE TRACK SYSTEM OF THE MAIN STATION AT MUNICH) P

Karnovsky, F.

Gas-und Wasserfach, vol.110, no.36, p.975-980, 1969.
The re-laying of a drainage channel near the tracks of the main station was involved in the construction of the rapid transit system between the main and the east station. The report presents subsoil conditions around anticipated construction method, the fundamentals of particular suggestions and injection grouting between the ground and the concrete.

START GEL TIMES WITH CHEMICAL GROUTS C

Karol, R.H.

Mining Magazine, vol.117, p.148-152, September 1967.

SEWER GROUTING CURES PLANT OVERLOAD PROBLEM C

Kemmet, R.H.

Public Works, vol.104, no.7, p.94-95, July 1973.
Discusses chemical grouting of leaks in sewage treatment plant using a TV camera for inspection of the work.

PRESSURE REQUIREMENTS FOR CONSOLIDATION GROUTING AROUND PRESSURE TUNNELS P

Khachikyan, G.G.G.

Hydrotechnical Construction, no.8, p.747-749, 1970, (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.8, p.42-43, 1970.)
Evaluations of the magnitude of the cement-mix pumping pressure necessary for deep grouting around hydraulic pressure tunnels driven in jointed rock formations. Theoretical basis for problems connected with consolidation grouting is difficult to establish.

THE GROUTING OF WELLS IN ROCK FORMATIONS

Kirchoffer, W.G.

Engineering and Contracting, p.141, August 11, 1920.

GROUTING WELLS IN ROCK FORMATION EFFECTIVE AND SIMPLE

Kirchoffer, W.G.

Engineering News-Record, vol.81, no.8, p.367, August 22, 1918.

PRESTRESSING OF THE LINING OF A HYDROTECHNIC TUNNEL IN A WATERTIGHT ROCK MASS BY GROUTING — P

Krsmanovic, D., Langof, Z., and Zupcevic, H.

Rock Mechanics (Journal of the International Society for Rock Mechanics), vol.1, no.1, p.71-89, July 1969.

Grouting of quartz sandstones and schists in a full scale model. Grout used was a porous injection solution for use at low pressures. (Required to remain porous after hardening and to develop a great hardness under pressure.)

ANCORAGENS PROVISORIAS EM SOLOS ARGILOSOS NO METRO DE SAO PAULO (PROVISIONAL ANCHORAGE IN CLAY SOILS DURING THE CONSTRUCTION OF THE SAO PAULO METRO) — P

Kuhn, B.A.

Brazil Society of Soil Mechanics and Foundation Engineering, 4th Congress, Rio de Janeiro, August 1970, Proceedings, vol.1, no.1, p.III-42 - III-93.

Discussion of principal construction system of prestressed tiebacks in soils, the general specifications for the design and testing of anchorages and the procedure and results of tests carried out on several sites of the Sao Paulo Subway. In Portuguese.

SOLUTION DU REVETEMENT D'UNE GALERIE EN CHARGE PAR APPLICATION D'INJECTIONS A HAUTE PRESSION (A PRESSURE TUNNEL LINING USING HIGH-PRESSURE GROUTING) — P

Kujundzic, B., Jovanovic, L., and Radosavljevic, Z.

International Society of Rock Mechanics, 2nd Congress, Belgrade, 1970, Proceedings, Theme 4, no.66, vol.2, p.867-881.

High pressure cement grouting was performed in the lining of the power plant headrace tunnel. A tunnel lining was designed on the basis of exploration works and constructed in the trial chamber and pressure grouting was carried out. In French with English summary.

REPORT ON THE CROSSING BY THE PRESSURE TUNNEL OF ROSELAND-LABATTIRE OF QUARTZITE SUBJECT TO CREEP — P

Lajeat, J.P., and Court, M.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, p.543-563.
Description of tunnel construction across a zone of crushed rock bearing water. Exploratory work discovered the zone and special grouting treatment solved the problem and no serious delays or difficulties resulted.

NORTH AMERICAN RAPID EXCAVATION AND TUNNELING CONFERENCE, CHICAGO, 1972, PROCEEDINGS

Lane, K.S., and Garfield, L.A., eds.

New York, Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, 1972, 2 vols.

LATEST GROUTING TECHNIQUES FOR £9m BLACKWALL TUNNEL

Municipal Engineering, vol.139, p.149-150, February 1962.

EFFECTIVE USE OF TV SEWER INSPECTION AND SEALING

Lenahan, T., and Herndon, J.

Public Works, vol.103, no.7, p.74-76, July 1972.
Discusses a grouting system which is used in conjunction with the TV inspection system. The TV operator is able to isolate revealed leaks with an air-inflated packer.

GROUND STABILIZATION: REVIEW OF GROUTING AND FREEZING TECHNIQUES FOR UNDERGROUND OPENINGS — C, P

Lenzini, P.A., and Bruss, B.

Washington, D.C., Department of Transportation, Federal Railroad Administration, FRA ORD&D 75-95, August 1974 - August 1975.
The ground stabilization techniques of grouting and artificial freezing are reviewed. General grouting considerations are discussed including selection of grouts and techniques of injection. Materials for both particulate and chemical grouts are described, along with their influence on ground properties and advantages and disadvantages.

LOW ALUMINA CEMENT USED IN GROUTING EAST BOSTON TUNNEL P

Engineering and Contracting, vol.51, p.390, April 16, 1919.

EXPERIMENTAL OBSERVATION ON GROUTING SANDS AND GRAVELS

Machis, A.

American Society of Civil Engineers, Transactions, vol.113, p.181-212, 1948.
Cementing of water wells in coastal regions to prevent infiltration of salt water.

CEMENTATION OF BITUMINOUS COAL MINE ROOF STRATA C

Maize, E.R., and Wallace, J.J.

Washington, D.C., U.S. Bureau of Mines Report of Investigations no.5304, November 1956.
Water and oil injection tests up to 1200 psi were forced into the roof rock with no bad effect on strata. This was followed by the Joosten grouting method using water glass and sodium chloride chemical with good results.

BRUNSWICK - AN INDUSTRIAL COMPLEX IN THE MAKING C, P

Mamen, C.

Canadian Mining Journal, vol.86, no.8, p.61-78, August 1965.
No.12 Mine and Concentrator of Brunswick Mining and Smelting Corp. Cement grout is a mixture of quick-setting cement Fonu and portland cement in the ratio of 2:5 with a setting time of about 20 minutes. Cement grouting done with a 1000 psi pump - combination double batch mixture and pump, (chemical grout also used.)

SHOTCRETE SUPPORT WITH SPECIAL REFERENCE TO MEXICO CITY DRAINAGE TUNNELS P

Mason, E.E., and Mason, R.E.

Rock Mechanics, (Journal of the International Society for Rock Mechanics), vol.4, no.2, p.115-128, October 1972.
The use of shotcrete is described as a structural support in tunnels in soft, water-bearing, semi-consolidated soil-rocks with an unconfined compressive strength ranging about 27 psi. No interior steel reinforcement was used in the transition section, though 3 m

grouted bolts were used for rock reinforcement of the arch. Shear and tensile stresses slowly developed in the walls about the transition section, which were then bolted. Abandoned for 12 months and left under water, floor heave of 30 cm developed, without damage to the shotcrete arch and walls.

WIRKSAMKEIT DER VERFESTIGUNGSINJEKTION DES GEBIRGES UM DIE TRIEBWASSERDRUCKSTOLLEN VON WASSERKRAFTWERKEN (EFFICIENCY OF ROCK CONSOLIDATION GROUTING IN MOUNTAINS AROUND INTAKE PRESSURE GALLERIES OF HYDROELECTRIC POWER PLANTS) P

Masur, A.

International Society on Rock Mechanics, 2nd Congress, Belgrade 1970, Proceedings, Theme 6, no.17, vol.3, p.247-252.
Deep grouting in combination with shotcreting can often replace the lining of pressure-water tunnels by improving the rock properties. Reports on grouting tests and operations for Inguri Tunnel in Russia. In German with brief English summary.

THE USE OF TUNNELING TO DEVELOP ARCTIC OIL AND GAS RESERVES

McCusker, T.G., and Tarkoy, P.J.

Washington, D.C., U.S. National Committee on Tunneling Technology, Tunneling Technology Newsletter, vol.15, p.1-6, September 1976.
Contains a brief discussion on grouting in tunnel construction during drilling operations in the Arctic.

WELL GROUTING AND WELL PROTECTION P

Moehri, K.E.

American Water Works Association Journal, vol.56, no.4, p.423-431, April 1964.
Discusses casing of wells, placement of grout, and mixing of grout in grouting and sealing of wells.

SOME NOTES ON PRE-GROUTING AT PRESIDENT BRAND GOLD MINING COMPANY, LTD.

Mudd, R.A.

Association Mine Managers South Africa, Paper and Discussions, p.141-164, 1958-1959, 1960.
Pregrouting of area around shaft decreased quantity of water intersected and increased speed of sinking and safety factor.

LONG-HOLE DRILLING WITH A PERCUSSION MACHINE DRIVING SHAFT-SINKING

Munro, R.

Mining Magazine, vol.116, p.39-40, January 1967.

HOUSTON INFILTRATION ABATEMENT PROGRAM C

Munson, E.D.

American Society of Civil Engineers, Journal of the Environmental Engineering Division, vol.99, no.EE-5, p.729-739, October 1973, Paper 10061.
Grouting of open joints and cracked pipes in sewer lines is discussed.

TUNNEL GROUTING IN BROOKLYN END OF CATSKILL AQUEDUCT P

Myers, O.W.

Engineering News, vol.76, no.5, p.196-200, August 3, 1916.
Methods of controlling water inflow while placing concrete lining and of grouting to stop subsequent leaks are described. Sequence of placing concrete lining is given; also method of controlling water by pans and piping and at worst place by steel lining to convey water to a drainage sump.

GROUT IS KEY TO DEWATERING JOB P

Nachtegaele, D.

Western Construction, vol.43, no.10, p.60-62, October 1968.
Dewatering problem on Bay Area Rapid Transit System solved by grouting. Describes equipment used for grouting which was done in three steps.

CONTROL OF UNDERGROUND WATER AT THE PORT RADIUM MINE P

Nancarron, W.C.

Canadian Mining and Metallurgical Bulletin, vol.50, p.28-35, January 1957.
In preventing the inflow of water into the mine workings of the Port Radium Mine, a grout mixture of cement with a sawdust admixture injected at 2,000 psi proved to be successful.

ZARUBEZNAJA PRAKTIKA CEMENTACIL GORNYCH POROD (FOREIGN PRACTICE IN CEMENT GROUTING OF ROCKS) P

Nasonov, I.D., and Galcenko, P.P.

Sachtnoe Stroitel'stvo, vol.15, no.2, p.25-28, 1971.
Methods used for sealing permeable rock layers in which a shaft or a tunnel is to be driven are surveyed. Survey includes USA, Great Britain, Canada, and Switzerland. Gives detailed information on the criteria for the permeability of the sealed rocks, requirements for grain size of cements and some of the results achieved.

SPRAY GROUTING--SUMMARY OF RESEARCH, DEVELOPMENT, UTILIZATION, AND FUTURE USES P

Nelson, C.R.

Minneapolis, University of Minnesota, NSF/RA/T-75/073, 8 December 1975.
A spray grouting technique has been developed for hardening a 1- to 6-inch surface layer of weak sandstones such as the St. Peter Sandstone in Minnesota. When used on tunnel walls and roof it provides temporary excavation support in larger tunnels and permanent lining in smaller utility tunnels. The technique is now being used in an 8,000-foot-long storm-water tunnel and in a 6,500-foot-long utility tunnel.

NEW METHOD FOR SOIL STABILIZING, GROUTING

South African Mining and Engineering Journal, vol.71, no.3515, p.1519, June 17, 1960.

NEW MINE SEALING TECHNIQUES FOR WATER POLLUTION ABATEMENT

Duncan, Okla., Halliburton Co.
Field testing was conducted on remedial grouting techniques developed for watertight mine seal.

TUNNEL DRIVING METHODS P

Noskiewicz, T.M., and Ramsay, J.A.

Engineering and Contract Record, vol.77, no.13, p.49-57, December 1964.
Various tunneling methods are examined and two methods of construction are discussed, "shield driven tunnels" and "sunken tube tunnels." New concepts of grouting are outlined.

USE OF POLYESTER-TYPE RESIN TO STABILIZE FRACTURED ROCK: A PROGRESS REPORT. C

Oitto, R.H.

Washington, D.C., U.S. Bureau of Mines, Report of Investigation, RI-6626, 1965.
Polyester-type resin and reinforcing bars (rebars) utilized in combination to strengthen and stabilize bolted, fractured wall rock in a gold mine. Fractured walls definitely strengthened by this process.

PARIS REGIONAL RAPID TRANSIT CUTS DEEP UNDER THE OLD CITY P

Engineering News-Record, vol.178, no.7, p.30-33, 16 February 1967.
Cement grout injected into small holes in each precast concrete segment to fill the space between the lining and the tunnel wall. A mechanical arm lined the roof of the tunnel with rows of precast concrete liner segments.

PUMPS SPEED GROUTING OF 20-MILE WATER TUNNEL UNDER NEW YORK

Park, A.S.

Compressed Air Magazine, vol.37, p.3922-3925, September 1932.

GROUTED ROCK BOLTS FOR PERMANENT SUPPORT OF MAJOR UNDERGROUND WORKS P

Pender, E.

Journal of the Institution of Engineers, Australia, vol.35, no.7-8, p.129-150, July - August 1963.
Grouted deformed shank bolts are used where bolt is to be part of permanent rock support system.

EFFECTIVE DEPTH OF GROUTING FOR HYDRAULIC PRESSURE TUNNELS

Ponimatkin, P.U.

Hydrotechnical Construction, no.4, p.356-357, April 1969. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.4, p.42, April 1969.)
A theoretical method for determining the depth of consolidation grouting for hydraulic pressure tunnels is developed on the basis of an analysis of the rock properties such as elastic deformation.

BENTONITE TUNNELLING SHIELD BREAKS NEW GROUND

Potey, D.R.

Contract Journal, vol.248, p.34-35, 21 September 1972.

PRECAUTIONS IN GROUTING TUNNELS AND SHAFTS

Engineering News-Record, vol.84, no.7, p.344, February 12, 1920.
Precautions to be observed in placing grout as a means of backing up and filling spaces behind tunnel linings, cutting off flows of water into shafts and tunnels, and solidifying dam foundations.

USE OF COMPRESSED AIR IN HANDLING MORTAR AND CONCRETE

Prentiss, G.L.

National Association of Colleges and Universities (NACU), Proceedings, vol.7, p.504, December 1910.
Grouting inner lining of tunnel on Paris, Lyons, and Mediterranean Railway Method.

PRESSURED GEL CUTS MINE SEEPAGE C

Engineering Mining Journal, vol.160, p.108, March 1959.
To control water seepage a chemical polymer grout (Hydro-Lok-PWG (AM-9)) was used. Initial viscosity approached that of water but where spaces were large enough, a resin cement was used as the building agent.

RAIL TUNNEL UNDERPASSES A RUNWAY IN HOLLAND C

Engineering News-Record, vol.178, no.16, p.42-44, 20 April 1967.
1640-ft tunnel placed through an area with a high water table. Tunnel under Amsterdam's Schiphol Airport. Deep-injection chemical soil stabilization was used.

SHAFT LINING AND GROUTING PROBLEMS ASSOCIATED WITH COTGROVE AND BEVER COTES SHAFTS C, P

Redfern, A., and Pinder, B.F.

Colliery Guardian, vol.209, no.540, p.817-826, December 18-25, 1964; vol.210, no.5411, p.15-21, January 1, 1965.
Sinking shafts through heavily watered strata, Nottinghamshire, England. Cement and chemical grouts used; majority of grouting done through concrete lining of shaft.

OIL WELL CEMENTING P

Reid, A.

Institution of Petroleum Technologists Journal, vol.18, no.99, p.53, 1932.

Tests on effect of contamination by admixture with mud during grouting of oil well shafts on tensile strength of portland cement mixes have confirmed results reported by Doherty and Manning in that strengths are decreased with increase of contamination. Such grouts show marked combination which may be attributed to carbon dioxide content of such mud.

METHOD AND COST OF GROUTING A WATER-BEARING FISSURE AND SEAMY ROCK IN SINKING A MINE SHAFT P

Reigart, J.R.

Engineering and Contracting, vol.44, p.353, November 3, 1915.

Describes 17 ft. diam. circular mine shaft sunk 102 feet through quicksand.

RUBBER FIBER WELL SEAL

Water Well Journal, vol.26, no.6, p.48, June 1972.

Discusses possible solution to the problem of polluted surface water seepage down the side of the well casing.

AIR-MORTAR GROUTING INTO BACK OF TUNNEL LINING P

Sakamoto, S.

Japan Society of Civil Engineers, Journal, vol.50, no.3, p.18-23, March 1965.

Use of air mortar as backfilling is discussed. The actual results of air mortar grouting used in backfilling of tunnels on New Tokaido Line.

GROUT SAVES MONTREAL TUNNEL C

Salmins, George

Engineering and Contract Record, vol.80, no.2, p.75-77, February 1967.

AM-9 chemical grout used to curb flooding into a subway tunnel under St. Lawrence River at Montreal. Water seeping at rate of 6000 gpm.

GROUTING OPERATIONS, CATSKILL WATER SUPPLY P

Sanborn, J.F., and Zipser, M.E.

American Society of Civil Engineers, Transactions, vol.83, p.980-1079, 1919-1920.
Grout was used extensively in the structures of the Catskill water supply system for filling spaces behind the lining of tunnels, for cutting off the flow of water into shafts and tunnels by grouting the water-bearing fissures, for solidifying the foundations and stopping the flow beneath dams, and for various other purposes. This paper gives a summary of the experience and results obtained in the use of grout in the construction of the aqueduct, dams, and other structures of the Catskill Works.

DAS VERFESTIGEN DES STRECKENMANTELS DURCH MOERTEL UND ZEMENTMILCH P
(STRENGTHENING OF DRIFT LINING BY MEANS OF MORTAR AND GROUT)

Schmidt, K.L.

Glueckauf, vol.99, no.20, p.1110-1113, September 25, 1963.
Concerning grouting in coal mining. Methods of grouting and experience with maintenance of drifts and tunnels after grouting; costs of grouting and advantages as compared with various methods of supporting galleries given.

MACHINE GROUTS JOINTS IN TRUNK SEWER

Seabrook, C.S.

Engineering News-Record, vol.138, no.2, p.50-52, January 9, 1947.
Describes method and equipment used in shooting mortar into joints of bell-and-spigot and tongue-and-groove concrete sewer pipe rather than using conventional mortar joints. Machine similar to gunite machine but smaller nozzle.

SEALING ABANDONED WATER WELLS

Water Well Journal, vol.27, no.4, p.31-32, 34. April 1973.
The use of grouting to seal an abandoned water well is examined.

SEPTEMBER START FOR DARTFORD TUNNEL GROUND TREATMENT

Contract Journal, vol.248, p.13, 24 August 1972.

GROUTING IN PILOT TUNNEL HEADING

Shinohara, Hiroshi, and Akita, Katsuji

Permanent Way, vol.14, no.3, p.12-23, April 1973.

SIX-LANE TUNNEL SITS ON SACKS OF GROUT P

Engineering News-Record, vol.179, no.19, p.104-105, 9 November 1967.
Tingstad Tunnel Gata River in Gothenburg Sweden. Cushion of grout contained in large plastic bags was placed between the tunnel and piles. Nylon sacks pumped full of grout to a form-fit between the tunnel bottom and the tops of the pile.

INFILTRATION OF GROUND WATER INTO SOIL SEWERS C

Smith, D.R., and Clifford, J.A.

Chartered Municipal Engineer, vol.90, no.6, p.169-175, June 1963.
Treatment of existing pipeworks in sewers by "terraseal" chemical grouting process.

SOFT GROUND TUNNEL GIVES JERSEY SEWER CONTRACTOR HARD TIME C

Engineering News-Record, vol.177, no.13, p.26-28, September 1966.
Low viscosity acrylamid used to stabilize bad ground under railroad tracks so that a tunnel could be driven. 32,000 lb of chemical grout used.

ELECTRIFICATION OF KOBLENZTRIER LINE; EXTENSIVE GUNITING AND GROUTING REPAIRS COMPLETED IN REILERHALS TUNNEL P

Spang, I.J.

Tunnels and Tunneling, vol.5, no.1, p.35-39, January-February 1973.
By constructing anchored concrete aprons in front of the exposed foundations, the costly underpinning of the foundations with mass concrete could be avoided. The preservation and strengthening and renewal of a displaced tunnel lining was achieved by the use of guniting and grouting techniques. It was proved that tunnel linings, stone packing behind, and loosened rock can be filled and strengthened free from cavities by injection of cement grout.

CITY TUNNEL OF CATSKILL AQUEDUCT

Spear, W.E.

Engineering News, vol.73, no.3, p.98-104, January 21, 1915.
Method of grouting in rock.

GROUTING EQUIPMENT FOR CITY TUNNEL, CATSKILL AQUEDUCT

Spear, W.E.

Engineering News, vol.73, p.894, May 6, 1915.

A DEFORMABLE MATERIAL FOR SAND CONSOLIDATION C

Spurlock, J., and others

Journal of Petroleum Technology, vol.18, no.3, p.306-312, March 1966.
A methane elastomer which is catalyzed by in situ ground water. Forms a rubbery, tough matrix which will undergo considerable movement without sloughing.

EFFECTS OF GROUTING AND GRAVEL PACKING AROUND TUNNEL P

Thompson, W.E.

Engineering News-Record, vol.90, no.14, p.617-619, April 5, 1923.
Results obtained by separate injection of screened gravel packing and cement grout through holes in cast iron lining of subway under Willoughby St., Brooklyn observed several years after operation. Grout mixture, consistency, methods, and pressures used.

TUNNEL SHAFTS BY ICOS BENTONITE METHOD M

Consulting Engineer, (London), vol.35, no.3, p.73-75, March 1971.
Discusses the use of bentonite gel for grouting during the construction of tunnel shafts. The mine shaft protection work showed that this method could be adapted to resolve other intricate foundation problems, such as in atomic power stations or the chemical industry.

TUNNELLING METHOD BREAKS NEW GROUND M

Surveyor, vol.140, p.27, 22 September 1972,
With a new method and equipment for tunneling through difficult sand and gravel, many more projects become practicable and economical. By the introduction of bentonite to the basic method used in tunneling through soft ground with an excavator shield, a technique has been developed capable of operation in non-cohesive ground. A tunneling machine is used in which the cutters revolve in a sealed chamber which is filled with thixotropic slurry of bentonite clay under pressure. The bentonite holds up the tunnel face, sinking into the gravel for some inches and forming a skin to seal it.

UNDERGROUND COAL MINING METHODS TO ABATE WATER POLLUTION: A STATE-OF-THE-ART LITERATURE REVIEW — C, P, M

Washington, D.C., Environmental Protection Agency, Water Pollution Control Research Series EP1.16:14010 FKK 12/70, December 1970.
A review of published information pertaining to the abatement of harmful drainage from underground coal mines. Discusses the use of new, and refinement of known grouting agents.

TUNNEL GROUTING, BLAKELY MOUNTAIN DAM — P

U.S. Army Engineer District, Vicksburg

Vicksburg, Miss., September 1950.
The grouting program was divided into initial low pressure operations and high pressure grouting. Generally, in the low pressure grouting operations, a mortar grout was used to fill the voids in the overbreak areas where tunnel lining concrete could not be placed and to fill the larger seams and cracks in the rock adjacent to the tunnel concrete. In the high pressure grouting operations, a neat cement grout was used to fill the smaller cracks and seams in the rock and any other voids which the low pressure mortar grout did not reach.

DESIGN, TESTING, AND FIELD PUMPING OF GROUT MIXTURES; FINAL REPORT, PROJECT GNOME, CARLSBAD, NEW MEXICO, DECEMBER 10, 1961 — P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., PNE-116F, March 1962.
The U.S. Army Engineer Waterways Experiment Station furnished drilling consultant services, and performed core testing and grouting operations in connection with work for the U.S. Atomic Energy Commission on Project GNOME. Grouting work included (a) performing physical tests and petrographic examinations on salt cores from the project site; (b) designing grout mixtures, to match physical properties of the salt, for use in grouting instruments in place and in connection with installing underground structural appurtenances; and (c) drilling and grouting at the site to embed scientific instruments, and in connection with structural work within the tunnel. This report was prepared by J. M. Polatty and R.A. Bendinelli.

DRILLING AND GROUTING SUPPORT; PROJECT COWBOY — C, P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-419, March 1961.

This report by J.M. Polatty, R.A. Bendinelli, T.B. Goode, and B.J. Houston describes drilling and grouting operations performed by the U.S. Army Engineer Waterways Experiment Station in connection with Project COWBOY. These operations included design of (a) saltgrouts for grouting instrument and for stemming HE shot holes drilled in the salt; (b) saltcrete for filling steel plugs used to seal the cavities; (c) saltgrout for grouting in place steel liners and walkways in access tunnels to the cavities; and (d) grouts for correcting for lost circulation of drilling mud in connection with the drilling of a 36-in.-diameter ventilation shaft into the mine. The Waterways Experiment Station also tested salt cores from the mine to determine their physical properties; furnished crews and equipment for drilling and grouting 10,629 ft of vertical, horizontal, and sloping holes of various lengths and diameters, for which special tools and techniques were developed, and determined in-place ultrasonic velocities of the salt near the cavities.

FERRIS WHEEL SERIES, FLAT TOP I EVENT, PROJECT OFFICERS REPORT - PROJECT 9.1; GROUTING SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-834, POR-3010 (WT-3010), November 1965.

In the Flat Top I event, 20 tons of high explosive, stacked in a spherical shape with the centroid at the ground surface, was detonated at the U.S. Atomic Energy Commission's Nevada Test Site (NTS). The primary purpose of this project was to study cratering and ground-shock phenomena of a detonation in hard rock. The U.S. Army Engineer Waterways Experiment Station determined pertinent physical properties of the dolomitic limestone and developed grout and concrete mixtures with similar properties, grouted seventeen drill holes and a grout pad, supervised the placing of concrete in major depressions about ground zero, and from field-cast grout and concrete specimens, determined their physical properties on detonation date. The specific gravity of both the grout and concrete mixtures was almost identical with that of the limestone, while the ultrasonic pulse velocities and compressive strength, though greater than conventional mixtures, were somewhat less than desired. A visual postshot examination of the crater and surrounding area indicated that the instruments were well embedded in grout, that good bond to instruments was obtained, and that grouting and concreting operations appeared to be successful. This study was done by J.M. Polatty, J.E. McDonald, and Howard Sugiuchi.

GROUTING IN SUPPORT OF UNDERGROUND NUCLEAR TESTING P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-914, April 1967.
In this report by R.A. Bendinelli and W.L. Burnett the development and placement of grouts in support of underground nuclear experiments is described. Support consists of consultation services for grouting programs; development of grout mixtures to meet experimental requirements, i.e., stemming of nuclear devices in deep drilled holes; coupling to formations associated instrumentation emplaced in deep holes drilled in various rock and alluvium formations; as massive plugs in shafts and tunnels; as shock-mitigation material behind tunnel liners, etc. Problems experienced and resolution of such problems are described.

LABORATORY AND FIELD GROUTING SUPPORT FOR PROJECT SCROLL P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.C-69-4, April 1969.
In Project SCROLL, a nuclear device was detonated at a depth of 750 ft in a vertical hole drilled in Area 19 of the U.S. Atomic Energy Commission's Nevada Test Site. The U.S. Army Engineer Waterways Experiment Station was responsible for (a) development of instrument-to-formation coupling grout mixtures embodying specified physical properties matching as closely as possible those of the formation at the project site, (b) development of an emplacement hole stemming grout, (c) supervision of the mixing and placement of the grout mixtures, and (d) determining, on detonation date, the pertinent physical properties of field-cast grout specimens representing the field-placed grout. In general, it is believed that the physical properties of the grout mixed and emplaced in the field closely matched those set forth in the design criteria. This report was prepared by D.M. Walley and T.L. Ellis.

OPERATION FLAT TOP, EVENT FLAT TOP I, PROJECT 9.1; GROUTING SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-706, February 1965.
This report by J.E. McDonald and Howard Sugiuchi discusses Project FLAT TOP I. Twenty tons of high explosive stacked in a spherical shape with the centroid at the ground surface was detonated at the U.S. Atomic Energy Commission's Nevada Test Site. The primary purpose of this project was to study cratering and ground-shock

phenomena of a detonation in hard rock. The U.S. Army Waterways Experiment Station determined pertinent physical properties of the dolomitic limestone and developed grout and concrete mixtures with similar properties, grouted seventeen drill holes and a grout pad, supervised the placing of concrete in major depressions about ground zero, and from field-cast grout, and concrete specimens, determined their physical properties on detonation date. The specific gravity of both the grout and concrete mixtures was almost identical with that of the limestone, while the ultrasonic pulse velocities and compressive strength, though greater than conventional mixtures, were somewhat less than desired. A visual postshot examination of the crater and surrounding area indicated that the instruments were well embedded in grout, that good bond to instruments was obtained, and that grouting and concreting operations appeared to be successful.

OPERATION FLINT LOCK, SHOT PILE DRIVER, GROUTING AND MATERIALS CONTROL P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.C-69-7, POR-4013(WT-4013), March 1969.

This report by G.C. Hoff, R.L. Stowe, and W.L. Burnett describes laboratory tests conducted and field support provided by the U.S. Army Engineer Waterways Experiment Station personnel for the U.S. Atomic Energy Commission on Project 3.5, Grouting and Materials Control. WES was responsible for the proportioning of grout mixtures used in filling holes drilled in the tunnel complex in which scientific instruments were to be embedded. An aluminous cement grout was designed that possessed static properties matching, as nearly as attainable, the corresponding properties exhibited by granodiorite. This grout was used to embed all instrumentation placed in native rock by Sandia Corporation, and the majority of instrumentation placed in native rock by Stanford Research Institute. An epoxy grout was synthesized that exhibited a Hugonoit equation of state similar to that exhibited by granodiorite. This grout was used to embed instrumentation placed by Stanford Research Institute in the region of hydrodynamic stresses. An extrudable neat cement grout was proportioned during the field construction phase and used to anchor the rockbolt portions of the scratch-type backpacking compression gauges installed by the U.S. Army Engineer District, Omaha. Postshot evaluation of the field-cast grout samples was made.

OPERATION NOUGAT, SHOT HARD HAT, PROJECT OFFICERS REPORT - PROJECT 9.1, GROUTING SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-575, POR-1807 (WT-1807), April 1963.

In Project HARDHAT, a low-yield nuclear device was detonated underground in granodiorite at the U.S. Atomic Energy Commission's Nevada Test Stie. The primary purpose of this project was to develop improved criteria and procedures for design of underground facilities in rock to provide protection against nuclear attack. The U.S. Army Engineer Waterways Experiment Station determined pertinent physical properties of the granodiorite and developed a grout mixture with matching properties; grouted 47 instrument holes and 2 postshot recovery holes; and from specimens of the field-mixed grout, determined its physical properties at shot time. The grout required a high water content to be pumpable; consequently, its compressive strength was less than desired. However, the density was almost identical with granodiorite and it is believed that the instruments were well embedded in and bonded to the grout and that the grouting operation was successful in all respects. This study was done by J.M. Polatty and J.E. McDonald.

OPERATION SUN BEAM, SHOT SMALL BOY; DESIGN, TESTING, AND FIELD PUMPING OF GROUT MIXTURES P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-628, POR-2253 (WT-2253), April 1963.

Project SMALL BOY involved the detonation of a low-grouting yield nuclear device in Area 5 of the U.S. Atomic Energy Commission's Nevada Test Site. In connection with this project, the U.S. Army Engineer Waterways Experiment Station was responsible for (a) design of a grout mixture with specified physical properties matching as nearly as possible those of the silt formation at the test site, (b) grouting of instrument holes and surface pressure-gage mounts, and (c) determining from specimens of the field-mixed grout its physical properties at shot time. Results of physical tests on the field-mixed grout specimens indicate that the maximum static tangent modulus of elasticity in compression was somewhat higher than desired; however, the density and ultrasonic pulse velocity of the grout satisfactorily matched that of the in-situ silt. It is believed that the grouting was successful and that it satisfactorily fulfilled the job specifications. This work was conducted by J.M. Polatty and J.E. McDonald.

PROJECT BUCKBOARD, GROUTING SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellanous Paper no.6-425, April 1961.

In Project BUCKBOARD, high-explosive charges were detonated in basalt to determine their earth-moving ability in this type of formation. One shot, 40,000-lb charge of spherically-shaped TNT, placed 43 feet below ground surface in an 11-foot-diameter cavity at the bottom of a 4-ft-diameter drilled hole, was to be used for ground-motion studies. The Waterways Experiment Station determined pertinent physical properties of the basalt and developed a grout mixture with matching properties for use in grouting earth-motion measuring instruments into eight holes drilled near shot 12, grouted the instrument holes, and from specimens of the field-mixed grout determined its physical properties at shot time. The grout required a high water content to be pumpable, consequently its compressive strength and ultrasonic pulse velocity were less than desired. However, it is believed that the instruments were well embedded in, and bonded to the grout, and that the grouting operation was successful. This report was prepared by R.A. Bendinelli.

PROJECT COWBOY, FINAL REPORT; DRILLING AND GROUTING SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., March 1961.

This report by J.M. Polatty, T.B. Goode, R.A. Bendinelli, and B.J. Houston describes drilling and grouting operations performed by the U.S. Army Engineer Waterways Experiment Station in connection with Project COWBOY. These operations included design of (a) saltgrouts for grouting instrument and for stemming HE shot holes drilled in the salt; (b) saltcrete for filling steel plugs used to seal the cavities; (c) saltgrout for grouting in place steel liners and walkways in access tunnels to the cavities; and (d) grouts for correcting for lost circulation of drilling mud in connection with the drilling of a 36-in-diameter ventilation shaft into the mine. The Waterways Experiment Station also tested salt cores from the mine to determine their physical properties; furnished crews and equipment for drilling and grouting 10,629 ft of vertical, horizontal, and sloping holes of various lengths and diameters, for which special tools and techniques were developed; and determined in-place ultrasonic velocities of the salt near the cavities.

PROJECT DANNY BOY; DESIGN, TESTING, AND FIELD PUMPING OF GROUT MIXTURES P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-640, POR-1826 (WT-1826), April 1963.

In Project DANNY BOY a nuclear device of low yield was detonated in basalt at the U.S. Atomic Energy Commission's Nevada Test Site as a part of weapons effects tests. The Waterways Experiment Station determined pertinent physical properties of the basalt and developed a grout mixture with matching properties for use in grouting scientific instruments in holes drilled near the shot location, grouted eight deep holes, and nine surface holes, and cast specimens of the field-mixed grout to determine its physical properties at shot time. A satisfactory, pumpable grout was developed. Grouting of the holes was accomplished without difficulty except that because of extremely cold weather, it was necessary to develop a quick-setting grout for the surface holes that would set before it froze. Due to the extremely cold weather, the test specimens obtained from the field-mixed grout froze before they could be properly cured in environmental conditions simulating those of the grout emplaced in the instrument holes; consequently, the compressive strengths of these specimens are not considered representative of the grout placed in the holes, and therefore, are not included in the report. However, it is believed that at the depths at which the instrument canisters were placed, the ambient temperature and humidity approached that of the laboratory in which the grout mixture was developed. Therefore, it is believed that the compressive strength of the grout in the immediate vicinity of the instruments approached that of the basalt, and that the grouting operation was successful. This report was prepared by G.V. Marler.

PROJECT DRIBBLE, SALMON EVENT; LABORATORY, DESIGN, ANALYSIS, AND FIELD CONTROL OF GROUTING MIXTURES EMPLOYED AT A NUCLEAR TEST IN SALT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper 6-773, VUF-3019, May 1965.

In the Project DRIBBLE, SALMON EVENT, the first of three planned events for the Dribble Program, a nuclear device was detonated near the bottom of a hole drilled vertically into a salt dome in Mississippi. This report describes work for the U.S. Atomic Energy Commission by the U.S. Army Engineer Waterways Experiment Station in (a) furnishing grouting consultant services and technical assistance in the field during grouting operations, (b) conducting stemming studies for the device emplacement hole, (c) developing formation-matching grouts for use in grouting instruments in place in deep

drilled holes, (d) providing instruments for hole temperature determinations, and (e) making physical tests on salt cores from the project site. Based on the results of this investigation, the following conclusions were made: Grout mixtures were successfully developed to meet all job requirements; modifying mixtures to meet depressed temperature requirements did not appreciably alter the desired physical properties of the mixtures. With the exception of one hole, all instrument holes were successfully grouted. Difficulties were experienced in other holes; however, various remedial actions solved these problems. The stemming operation for the device, hole was highly successful in all respects. Modifications and the addition of supplemental mixing equipment to the grouting systems considerably improved the quality control of the grout mixture. This improved quality control is believed to have been largely responsible for the successful grouting of the device and instrument holes. This report was prepared by J.M. Polatty and R.A. Bendinelli.

PROJECT GNOME; DESIGN, TESTING, AND FIELD PUMPING OF GROUT MIXTURES P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-514, PNE-116F, July 1962.

In Project GNOME, a nuclear device was detonated at the end of a buttonhooked and self-sealing tunnel excavated in a salt formation in New Mexico. The primary purposes of the project, were to explore (a) the feasibility of recovering and converting for electric power generation, energy from heat reservoirs formed underground by nuclear explosions, and (b) the practicability of recovering radioisotopes for peaceful uses. The U.S. Army Engineer Waterways Experiment Station furnished drilling consultant services, and performed core testing and grouting operations in connection with Project GNOME. The latter included (a) performing physical tests and petrographic examinations on salt cores from the project site; (b) designing grout mixtures to match physical properties of the salt for use in grouting instruments in place and in connection with installing underground structural appurtenances, and (c) drilling and grouting at the site to embed scientific instruments in connection with structural work within the tunnel. This report was prepared by J.M. Polatty and R.A. Bendinelli.

PROJECT HANDCAR/PAINTED PONY; PROJECT 9.1, LABORATORY AND FIELD GROUTING AND MATERIAL SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-875, February 1967.

In Project HANDCAR/PAINTED PONY, a low-yield nuclear device was detonated in a vertical hole at the U.S. Atomic Energy Commission's Nevada Test Site. The U.S. Army Engineer Waterways Experiment Station was responsible for: (a) design of instrument grout mixtures with specified physical properties matching as nearly as possible those of the subsurface formations at the test site, (b) design of a stemming grout mixture with specified heat of hydration and compressive strength properties, (c) supervision of the field mixing and pumping of these grout mixtures, (d) supervision of the device emplacement hole stemming operations, (e) providing necessary instrumentation to determine levels of grout and pea gravel down-hole, and (f) determining the physical properties of field-mixed grout specimens on device detonation date. In general, it is believed that the grout mixtures possessed pertinent physical properties within an acceptable range of the design criteria. In practically all cases, instrumentation designed to determine levels of grout and pea gravel down-hole performed as desired, and it is believed that the grouting operations were successful in most respects. This report was prepared by J.E. McDonald.

PROJECT HOBO, GROUTING SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-409, August 1960.
The grouting operation was conducted by J.M. Polatty and Melvin Glass in connection with Project HOBO and consisted of four high-explosive shots made underground in tuff at the Nevada Test Site to permit a comparison between the seismic signal generated by a contained explosion in tuff and that produced by a tamped detonation in salt. To obtain shot data, three sets of instruments were placed in holes at the test site. Grouting mixtures were specially designed to match the density and sonic velocity of the in-situ material in which the instrument holes were drilled, and the instrument holes were pumped with these mixtures after the instruments were embedded. Three shot holes were drilled and pumped with a quick-setting grout mixture for containing the detonation of the high explosive, Pelletol, and a fourth hole was drilled and filled with a special set of mixtures to provide a dry hole for the detonation of the Pelletol. Field-cast grout specimens were tested in the laboratory. The field grouting was considered successful, and laboratory test results of the field-cast specimens checked the results of density tests made in the field.

PROJECT PRE-SCHOONER; REPORT 2: STEM DESIGN AND SHOTCRETE, GROUT, AND CONCRETE SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-660, Report no.2, PNE 501F, January 1965.

Project PRE-SCHOONER consisted of four 20-ton chemical-explosive detonations in grouting hard, dry, rock at scaled depths of burst. The primary purpose of the project was to increase the knowledge of crater dimensions in hard, dry rock as a function of depth of burst and type of explosive. This report describes the following work performed for the project by personnel of the U.S. Army Engineer Waterways Experiment Station: (a) the design and placement of grout mixtures used in grouting satellite holes surrounding each ground zero location, (b) the design and supervision of the placement of a shotcrete mixture used in lining the walls of each of the shot cavities, and (c) the design and supervision of the placement of a concrete mixture used in stemming the access holes to each of the shot cavities. This report was prepared by K.L. Saucier, J.C. Wines, and G.V. Marler.

SPECIAL GROUTING OPERATIONS FOR UNDERGROUND NUCLEAR TESTS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellanous Paper no.6-429, April 1961.
This report discusses the development of several different grout mixtures to be used at various holes within the tunnel for underground nuclear tests. This report was prepared by J.M. Polatty and R.A. Bendinelli.

DIFFICULT EXCAVATION AT CARLEY PORTER TUNNEL C

Varello, P.J.

Civil Engineering, vol.40, no.6, p.66-69, June 1970.
Running and caving ground conditions, and collapse of a tunneling shield caused many problems in this 5-mile tunnel. Grouting methods discussed.

ZPEVNOVANI HORNIN INJEKTAZI NA PRAZSKEN METRU (SOLIDIFYING OF SOILS AND ROCKS FOR THE UNDERGROUND RAILWAY IN PRAGUE) C

Verfel, S.

Inzenyrske Stavby, vol.22, no.7, p.355-363, 1974.
A description of the main grouting works in constructing the underground railway in Prague. Sandy gravel and the upper beds underlying it were grouted. At first, a clay-cement mixture had been injected, followed by a chemical grout. For the chemical grout, waterglass and artificial resins were used.

MINE SAFETY AND UNDERGROUND SUPPORT STRUCTURES ROCK IMPREGNATION AND PUMPABLE ROCKBOLT DEVELOPMENT: FINAL REPORT. C

Waide, C.H., and others

Upton, New York, Brookhaven National Laboratory, Associated Universities, Inc., Department of Applied Science, for the Bureau of Mines, United States Department of the Interior and the Division of Applied Technology, United States Atomic Energy Commission, Washington, D.C. June 1973.

A three-year program, conducted for the U.S. Bureau of Mines and directed by the Spokane Mining Research Center, has resulted in the development of a pumpable roofbolt, the study of coal-mine rock impregnation materials and their effectiveness, the development of three-dimensional finite-element computer techniques for the analyses of mine structures, and the development of a mine structure monitoring technique based on computer scanning of photo-deformation measurements. The pumpable roofbolt system is based on the installation of a reinforcement consisting of flexible bundles of continuous glass roving fibers delivered from reels into a drill hole simultaneously with the pumping in of a high-flash-point fire-retardant polyester resin filled with milled glass fiber. The process was demonstrated by three field tests at the White Pine Copper Company Mine in Michigan. In the last test, a roof support test involving 150 bolts placed in a mine intersection, after five months the roof condition compared favorably with that of an adjacent intersection bolted with resin-grouted bolts. In the rock impregnation work, several monomers and resins and a variety of impregnation techniques were used with coal-mine shale and coal.

DRIVING A WET AQUEDUCT IN HARD ROCK P

Wait, B.H.

Engineering Record, vol.63, p.660-662, June 17, 1911.
Difficulties in vicinity of shaft no.4 in Rondout siphon.

TUNNEL GROUTING WITH PUMPS P

Warren, L.G.

Engineering News, vol.76, no.15, p.702-703, October 12, 1916.
Successful use of Cameron pump to pump grout behind tunnel lining.

GROUTING IN SOUTHEAST MISSOURI DISTRICT P

Weigel, W.W.

American Institute of Mining and Metallurgical Engineers, Technical Publication no.2427, "Symposium on Grouting," p.20-23, 1948; also Mining Technology, vol.12, September 1948.
Discusses mass grouting of large areas from the surface using flotation tailings spoken of as "slime." "Follow-up" grouting work is discussed in both slimed and unslimed areas. Actual grouting equipment consists of the pressure pumps, mixing barrels, and connecting hose and pipe. Actual order of grouting varies somewhat. If the channel in the face is thought to have a large amount of thin mud, clear water may be pumped out first to get room for the cement grout. If the face is badly shattered and broken with many leaks, a small amount of very thick grout may be pumped slowly and then allowed to set.

GROUTING THE CONCRETE LINING OF THE RONDOUT PRESSURE TUNNEL

Wittstein, H.L.

Engineering Record, vol.64, p.772-774, December 1911.
Description of difficulties, illustrations and drawings.

VEBERBLICK UEBER DIE IM BERGBAU VERWENDETEN INJEKTIONSVERFAHREN (SURVEY OF GROUTING METHODS USED IN MINING) P

Woehlbier, H., and Baston, K.

Bergbauwissenschaften, vol.11, no.9-10, p.197-204, May 25, 1964.

APPLICATION OF CEMENTATIONS IN MINING C, P

York, L.A.

Canada Mining and Metallurgical Bulletin, vol.54, no.587, p.263-267, March 1961.
Cementation and silication processes; shaft sinking in fissured ground; drifting through fissured ground; shaft sinking through porous sandstones and unconsolidated formations; chemical grouting and chrome-lignin process or AM-9 process.

GROUTING "PRAIRIE SEDIMENT" P

York, L.A.

Canadian Mining and Metallurgical Bulletin, vol.57, no.621, p.63-67, January 1964.

Paper outlines the type of water-bearing formations encountered in the Prairie Sediments and describes method for effectively sealing these zones in order that shaft-sinking operations may be carried out safely.

SEALING GROUNDWATER OFF FROM CABLE BORES M

Ziemke, P.C.

Power Plant Engineering, vol.49, p.109, September 1945.
Well drill-hole 580 feet deep intersected broken ground causing large flow of water. Used bentonite mixed 15 bags to 40 gallons of water. Pumped down outside of casing at pressures of 100 psi. Sealed off all flows.

V. - ROADBEDS, PAVEMENTS

THE ART OF SLABJACKING CONCRETE PAVEMENTS P

Rural and Urban Roads, p.41-45, February 1968.
Through slabjacking, the pressure pumping of a fine aggregate and portland cement grout under concrete slab pavements, concrete pavement life can be greatly extended, original riding qualities preserved, and cracking due to nonuniform subgrade support avoided. This article describes pumping, advanced pumping and faulting, faulting caused by densification, embankment settlement, settlement over culverts, settlement of approach slabs, location of holes, and grout mix design.

ASPHALT-CEMENT GROUTING RESTORES STABLE ROADBED ON SANTA FE M

Railway Engineer and Maintenance, vol.40, no.11, p.1016-1022, November 1944; also in Railway Age, vol.188, no.2, p.142-144, January 1945.

SPECIFICATIONS FOR UNDERSEALING PORTLAND CEMENT CONCRETE PAVEMENTS WITH ASPHALT M

Asphalt Institute

College Park, Md., Specifications Series no.6, December 1966.
Specifications for undersealing portland cement concrete with hot asphalt. Includes description, materials, equipment, construction, and method of measurement.

ASPHALT MEMBRANES, THEIR POTENTIAL USES IN HIGHWAY AIRFIELD PAVEMENT DESIGN M

Benson, J.R.

Roads and Streets, vol.95, no.12, p.78-80, 1952.
Experimentation with such devices as buried bituminous envelope, which wraps up the subgrade soil at optimum moisture and maximum compaction, is expected to be accelerated by the development of special asphalts.

BETTER PAVING BETWEEN TRACKS FOR INDUSTRIAL YARDS

Engineering News-Record, vol.123, no.25, p.829, December 21, 1939.
Grouted ballast at Cleveland, Ohio.

METHOD AND COST OF GROUTING BRICK PAVEMENTS

Bilger, H.E.

Engineering and Contracting, vol.46, p.502, December 6, 1916.

CEMENT-GROUTED CONCRETE ROADS P

Indian Concrete Journal, vol.24, p.216-217, September 15, 1970.
Description of experimental road construction using "Cheecol" grouted lengths and colloidal concrete lengths.

HOW TO DETECT AND CORRECT PAVEMENT SLAB PUMPING P

Chadwick, J.E.

Concrete Construction, vol.7, no.8, p.227-232, August 1962.
Gives early recognizable signs of slab pumping and describes procedures of correcting it by mud jacking. Sandy loam or loam top soil are best adapted for mixture material. Addition of emulsified asphalt may be desirable to increase the durability of mixture.

CHEMICALS SOLIDIFY SUBBASE C

Construction Methods and Equipment, vol.48, no.1, p.137-138, February 1966.
Sand stabilization was accomplished quickly with a minimum of equipment by pumping a special quick setting chemical grout into unstable sub-strata. The one-shot chemical grout method was used to solidify a gray-white shell and silty sand subbase under the 500-ft-long rail system that supports a 240-ft-high missile gantry at Cape Kennedy.

CONCRETE STREET RAILWAY TRACK FOUNDATION CONSTRUCTED BY PENETRATION, BALTIMORE, MD. P

Compton, R.K.

Engineering and Contracting, vol.45, p.334, April 5, 1916.
The penetration method was used in railway track foundation. The tracks were brought to the exact grade by ballasting, and then a thin cement grout was applied.

CORRECTION OF PAVEMENT PUMPING BY MUDJACKING, UNDERSEALING, CONCRETE REPLACEMENT, CRACK SEALING, AND SUBSEQUENT RESURFACING — P

Corder, L.W.

Washington, D.C., Highway Research Board, Proceedings, vol.28, p.311-320, 1948.
Discusses the "slab pumping" technique as used to repair portland cement concrete pavements in Missouri.

CURRENT ROAD PROBLEMS: MAINTENANCE METHODS FOR PREVENTING AND CORRECTING THE PUMPING ACTION OF CONCRETE PAVEMENT SLABS

Washington, D.C., Highway Research Board, Current Road Problems, no.4-R, Revised Edition, September 1947.
Describes methods for slabjacking and undersealing of pavements.

MUDJACKING IN NORTH CAROLINA — P, M

Davis, B.W.

Roads and Streets, vol.86, no.8, p.43-44, August 1943.
Spacing and location of holes depend upon the condition and dimensions of the slab. The mud, under pressure, will tend to flow in all directions about the same distance from the hole. Therefore, the holes should lie in a circular pattern about each other. Soil used in the mix to be pumped under the pavement should be loose, loamy topsoil, or a friable clay soil. When the mix is used for preventing or correcting the "pumping action" of a pavement slab it should be thin. Portland cement, plaster of paris, calcium chloride, and/or asphalt will be added to the mix in varying quantities, to meet the existing subgrade conditions.

RIGID PAVEMENT MAINTENANCE FOR AIRFIELDS — P

Duvall, B.U.

American Society of Civil Engineers, Journal of the Aerospace Transport Div., no.AT-1, p.57-76, September 1967, Paper 5457.
The use of grouting materials for the repair of airfield pavements is discussed.

LANDSLIDES AND ENGINEERING PRACTICE — P

Eckel, E.B., ed.

Washington, D.C., National Research Council, Highway Research Board, Special report no.29, 1958.

Discusses use of normal injection methods of portland cement and a sodium silicate grout to prevent landslides along highway and railroad rights-of-way.

DEVELOPMENT OF CEMENT-SLURRY MIXTURES FOR USE IN CORRECTING PUMPING PAVEMENTS P

Goetz, W.H.

Washington, D.C., Highway Research Board, Proceedings, vol.27, p.232-244, 1947.

Cement-slurry mixtures have been developed which have desirable workability characteristics and which are made with portland cement as the minor active ingredient. These mixtures have an initial, almost water-thin consistency, which is maintained for a controlled length of time, at the expiration of which a fast thickening action takes place. After thickening has occurred, the slurry mixtures set rapidly so that very little bleeding takes place and consequently their original volume is maintained.

THE CITY AND SOUTH LONDON RAILWAY; WITH SOME REMARKS UPON SUBAQEOUS TUNNELING BY SHIELD AND COMPRESSED AIR

Greathead, J.H.

Institution of Civil Engineers (London), Minutes of Proceedings, vol.123, p.39-123, 1896.

TREATMENT OF PUMPING PAVEMENTS WITH CEMENT SLURRY MIXTURES P

Green, F.H.

Washington, D.C., Highway Research Board, Proceedings, vol.27, p.245-257, 1947.

This is a report of experimental treatments for correction of pumping pavements on three test sections in Indiana, using a mixture of portland cement and calcium aluminate cement as a filling material. The experimental use of a mechanical pavement jack, in connection with the slurry treatments to correct faulted joints, is also reported.

GROUTING LIFTS SAGGING PAVEMENT P

Western Construction, vol.44, no.10, p.41-42, 46, October 1969.

Depressions in new pavement through Cajon Pass are lifted to within .005 ft of original grade by injections of cement grout under pressure.

LOUISIANA SLABJACKING STUDY P

Higgins, C.M., Kinchen, R.W., and Melancon, J.L.

Baton Rouge, La., Louisiana Dept. of Highways, Research Report no.45.
This study was primarily oriented toward slabjacking procedures for raising slabs and filling voids on roadways and at bridge approaches, with special emphasis on Louisiana materials and equipment.

MUDJACKING IN TEXAS P

Hodges, M.B.

Roads and Streets, vol.89, no.8, p.86-90, August 1946.
Over 150 miles of pavement successfully treated with a mixture of loam, RC-2 cutback, portland cement, and water.

ILLINOIS JACKS UP PAVEMENT P, M

Engineering News-Record, vol.125, no.19, p.47-49, November 7, 1940.
To save a 4-year-old concrete superhighway from disintegration over a pumping subgrade, Illinois is jacking up 25 miles of four-lane pavement by forcing a slurry of oil, cement, lime dust, loam, and water through holes drilled in every slab section. This procedure lifts sunken slabs and seals open joints. Combination nozzles take the slurry from a mud jack and compressed air from a compressor.

SLABJACKING, ART AND SCIENCE, RESTORING AND MAINTAINING THE PAVEMENT P

KaWala, E.L.

Concrete Construction, vol.14, no.2, p.53-57, February 1969.
Discusses all aspects of slabjacking, sometimes called mudjacking, which consists of maintaining or correcting the crown and profile of a concrete pavement by injecting cement grout under the slab.

SUBGRADE TREATMENT BY MUD-JACKING AND FILLING P

Kunzor, P.J.

Roads and Streets, vol.83, no.11, p.37-42, November 1940; vol.83, no.12, p.50-54, December 1940.

This article discusses "pumping" at pavement joints, its causes and effects. Also discussed are the methods and equipment used by the Illinois State Highway Department to stop pumping action and correct damage done.

IMPROVED MUDJACKING P

LaFleur, W.J.

Public Works, vol.44, p.90-92, January 1963.
Refinements in mudjacking techniques, equipment and materials are helping the New York State Thruway Authority in its major program of pavement maintenance.

SUBSEALING CONCRETE PAVEMENTS M

Linzell, S.O.

Association of Asphalt Paving Technologists, Proceedings, vol.16, p.3-30, 1947.
This paper discusses subsealing which involves the forcing of a plastic bituminous material under concrete pavement slabs, thereby sealing joints and cracks from underneath to prevent the entrance of surface water. Discussion by H.A. Wallace and an amplification by N.H. Truax are included.

MAINTENANCE MANUAL P

Charleston, W.V., West Virginia Department of Highways.
Contains information on slabjacking of all types of pavements.

SULPHUR CONCRETE WITH PARTICULAR REFERENCE TO PAVEMENT CONSTRUCTION C

McNeil, G.M.

Christchurch, England, Military Vehicles and Engineering Establishment, Report no.76509, February 1976.
Work was done to meet the military requirement for a rapid and economic method of preparing structural pavements. Use of sulphur concrete generally is discussed and suggestions for the use of grouted concrete in structures other than pavements are put forward. Possibility of modifying the properties of the material by the use of additives is also discussed.

IMPLEMENTATION OF SLABJACKING STUDY P

Melancon, J.L.

Baton Rouge, La., Louisiana Department of Highways, January 1972.
Gives results of a 4-day workshop on slabjacking.

PUMPING JOINTS SEALED BY MUDJACKING ASPHALT CEMENT (OHIO) M

Metcalf, H.D.

Roads and Streets, vol.86, no.5, p.53-54, May 1943.
The procedure is similar to mudjacking but no general raising of slab area is involved. A hole 2 1/2 in. in diameter is drilled in the pavement at a point about 15 in. from the joint. A pipe fitting of special design is inserted tightly into the hole. Water accumulated under the pavement around the joint is then blown out with compressed air. After the free water and thin mud have been blown out, then comes the pumping of bituminous material to quickly fill the void and seal the joint or crack.

METHOD AND COST OF GROUTING BRICK PAVEMENTS P

Engineering and Contracting, vol.46, p.502, December 6, 1916.
Discussing grouting techniques and equipment used by the Illinois State Highway Department.

MUDJACKING COSTS REDUCED AND QUALITY OF WORK IMPROVED P

Chicago, Portland Cement Association, Concrete Highway and Public Improvement, September-October 1941.

NEW TECHNIQUE USES POZZOLAN TO RAISE ROAD P

Better Roads, vol.41, no.4, p.18-19, April 1971.
Discusses reconstruction of Willamette River Bridge near Portland, Ore.
Injection holes were drilled through the slab and a pocket was washed out horizontally under the slab with a special tool to create a cavity into which the grout slurry was injected. Pumping began at the lowest point of the slab with a very thin slurry. When it was evident that the hole was "taking" grout, the mixture was thickened. The slurry consisted of one part of portland cement and three parts of pozzolan, an expanding agent that offsets shrinkage of the mix, and a fluidifying agent.

ASPHALT EMULSION FOR UNDERSEALING RIGID PAVEMENTS M

Ostrander, V.L.

Washington, D.C., Highway Research Board, Proceedings, vol.33, p.359-361, 1954.

This is a short description of subsealing, void-filling, and joint-filling work done with emulsified asphalt on the state highway system in New York. In the early stages of the work the emulsion was introduced by simply pouring it from hand-pouring pots. Soon after the initiation of the work it became apparent that greater speed and better results would be had if holes were drilled through the slabs and the asphalt introduced under pressure. As pressure application began, the joint filling from beneath became apparent. The emulsion oozed up through openings and would make its appearance 20 feet or more away from the point of injection. The success in stabilizing broken concrete pavements by this subsealing method has led to its use under other types.

SUBSEALING OF CONCRETE PAVEMENTS

Perry, B.F.

Washington, D.C., Highway Research Board, Bulletin no.322, p.30-33, 1962.

This paper concerns the experiences of the New York Department of Public Works with the salvage and restoration of old concrete pavements. These pavements were pumped badly and due to loss of subgrade support were consequently being weakened under the pounding of heavier and greater volumes of traffic. The methods used, their application, and the results obtained, are discussed.

THE PUMPING OF CEMENT GROUT INTO MASONRY ON THE METROPOLITAN RAILWAY, PARIS P

Engineering News, vol.62, no.22, p.581-582, November 25, 1909.

Cement grouting behind tunnel walls was placed by a number of experimental means, but compressed air proved best. The grouting was used to strengthen the arches or to fill up holes left in construction.

RESURFACING ASPHALT WITH CEMENT GROUT P

Public Works, vol.74, p.22, November 1943.

The grout was applied evenly by hand-brooming at the rate of 0.71 ton of cement and 1.4 cubic yards of sand per 1000 square yards.

SANTA FE STABILIZES 106 MILES OF ROADBED P, M

Railway Age, vol.118, no.2, p.142-144, January 1945.
Describes the method of asphalt-cement roadbed grouting employed on the A.T. & S.F. to fill water pockets and stabilize the track generally.

THE PARTITION OF CALCIUM AMONG CEMENTING COMPOUNDS IN AGING HIGHWAY CONCRETES

Simond, D.E.

Ames, Iowa, Iowa State University, M.S. Thesis, 1968, 82p.
This thesis is a study of petrographic evidence that changes occur in aging concretes. The use of grouting is discussed.

SLAB-JACKING, ANOTHER WAY TO MAINTAIN BETTER ROADS FOR LESS MONEY P

Better Roads, vol.44, no.12, p.33-35, December 1974.
Slabjacking is the pumping of a slurry beneath an existing concrete surface to fill the voids caused by erosion of sub-base material. This article discusses this operation including location of the pumping holes, raising the pavement slabs, and highway bridge approaches.

SLABJACKING CONCRETE PAVEMENTS P

Portland Cement Association, Concrete Information, IS 060.01P, 1967.
Slabjacking consists of maintaining or correcting the crown and profile of a concrete pavement by injecting a grout under the slab. The grout fills voids under the slab, thereby restoring uniform support. This document discusses the principle of slabjacking including location of holes, pumping, and grout mix design.

SPECIAL PAPER ON THE PUMPING ACTION OF CONCRETE PAVEMENTS

Washington, D.C., Highway Research Board, Research Report no.1D, 1943.

REINFORCED EARTH BRIDGES HIGHWAY SINKHOLE

Steiner, R.S., and Trojan, E.J.

Civil Engineering, vol.45, no.7, p.54-56, July 1975.
Faced with an unusual sinkhole condition, the Pennsylvania Department of Transportation decided to utilize a two-way reinforced earth

slab in conjunction with a subsurface grouting program to stabilize a roadbed area. The reinforced earth slab proved to be less expensive and quicker to construct than a comparable concrete slab. Although the earth slab was designed to bridge a 50-ft void, the grouting program would inhibit such a large void from forming. Extensive subsurface exploration, including development of an electronic resistivity profile, indicated conventional bridge structures could not be properly supported.

ALTUS AFB DEEP SOIL LAYER STABILIZATION TEST SECTIONS. VOLUME II: INSTRUMENTATION, CONSTRUCTION, AND DATA COLLECTION — M

Triandafilidis, G.E., and Bickle, L.W.

Albuquerque, N.M., New Mexico University, Final Report, 1 March 1973-31 December 1974, August 1975.
The basic objective of the research program was to select an airfield with a weak subgrade and to study the strengthening of the subgrade by using different stabilization procedures which included post-hole pile stabilization, drill-hole lime stabilization, and lime stabilization by pressure injection.

RESTORATION OF LANDING-MAT-SURFACED SUBGRADES BY GROUTING METHODS — P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.S-70-19, June 1970.
The use of cement and asphaltic materials as grout for the repair for pumped subgrades under heavy-duty airfield landing mats was studied. It was concluded that portland cement grouting could be used as a repair technique when the subgrade damage was confined to a relatively small portion of the mat-covered area. This report was prepared by C.D. Burns and V.C. Barber.

REPAIR OF RIGID PAVEMENTS USING EPOXY RESIN GROUTS, MORTARS AND CONCRETES — C, P, M

U.S. Dept. of the Army

Washington, D.C., Technical Manual no.5-822-9, 1968.
This manual presents materials, criteria, and procedures for expeditious repairing of uncontrolled cracks and spalls in airfield, road, and other rigid pavements by using epoxy resin grouts, mortars, and concretes.

A STUDY OF CONCRETE SLAB JACKING SLURRIES

Webb, J.D.

Jackson, Miss. Mississippi State Highway Department, MSHD-RD-73-058-1, September 1973.

This report on slab jacking slurries considered the literature which was available on the subject. Some laboratory testing was also conducted. Observation of actual field operations and experiments were made. From facts gathered, a gradation for the fine sand was established. The quantities of calcium chloride for specific temperature ranges were developed. The batching procedure for best results was determined. The findings of this study indicate that the water content of the mixture has the most pronounced effect on setting time, strength, and shrinkage. Using the findings of this study will produce excellent results for stabilizing pumping slabs.

MAINTENANCE METHODS FOR PREVENTING AND CORRECTING THE PUMPING ACTION OF CONCRETE PAVEMENT SLABS--MISSOURI P

Whitton, R.M.

Washington, D.C., Highway Research Board, Proceedings, vol.24, p.226-227, 1944.

Discusses the type of concrete pavement failure that is causing concern in Missouri as a result of "slab pumping" or the deflection of the pavement under a moving load. "Slab pumping" is the ejection of water thru the joints and cracks in concrete pavements carrying soil particles from the subgrade. Continued "slab pumping" results in voids under the concrete pavement and finally the breakdown of the pavement itself.

PUMPING OF RIGID PAVEMENTS IN INDIANA P

Woods, K.B., and Shelburne, T.E.

Washington, D.C., Highway Research Board, Proceedings, vol.23, p.301-316, 1943.

Pumping action as well as the factors affecting pumping are described. Pumping is prevalent during periods of heavy rainfall on those roads which carry a large volume of heavy truck traffic. Test results on samples of pumping soils show that pumping generally occurs on plastic clay-like materials. In Indiana these soil areas are lacustrine deposits, unweathered parent materials of the Wisconsin Drift, weathered shales, and soils with claypan or "B" horizon development. These studies reveal that on new construction, pumping can be minimized or eliminated by employing corrective measures.

VI. - SOILS

BODEMVERSTEVIGING MET BEHULP VAN CHEMISCHE INJECTIE (SOIL STABILIZATION USING CHEMICALS) C

Aerts, G.F.

Hague, Netherlands, Adriesbureau der Genie, Report no. ABG-235, February 1973.

PRESSURE GROUTING SOLVES THREE CASES OF SETTLEMENT P

Allen, G.P.

Municipal Engineering, vol.141, p.536, 27 March 1964, Paper 3873. Discusses subsoil injection by pressure grouting, grouting of refuse foundations, and grouting in peat.

AM-9 CHEMICAL GROUT C

Wayne, New Jersey, American Cyanamid Company, Technical Data, 1965. AM-9 is applied in water as a nonviscous solution and will penetrate any formation through which water flows. After the addition of a catalyst, the solution is injected or percolated into a soil or rock mass. In a predetermined period of time, which may be closely controlled from a few seconds to several hours by proper choice of catalyst, the AM-9 solidified to a stiff gel. The characteristics of the chemical reaction are such that the viscosity of the AM-9 solution remains essentially that of water until just before the gel forms. AM-9 has been used to seal off the flow of underground water into oil wells, drill holes, basements, tunnels, mine shafts, coffer dams, sewer pipe joints, caissons, sealing piezometers and open excavations. Of special interest is the use of AM-9 to seal underground curtain walls in and around dams or dikes. AM-9 is particularly effective for solidifying granular soil masses during tunneling operations, during the sinking of caissons, and in many types of shafts and excavations.

CUT-OFF EFFICIENCY OF GROUT CURTAINS AND SLURRY TRENCHES M

Ambraseys, N.N.

Grouts and Drilling Muds in Engineering Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, 1963, ed. by A.D.M. Penman, p.43-46. London, Butterworths, 1963.

Effect of imperfections on the seepage losses through imperfect cutoffs by theoretical evaluation. Water-retaining structures with imperfect cutoffs extending down in impervious strata are discussed. Includes two design charts.

AMELIORATION DES MASSIFS ROCHEUX CRISTALLINS PAR INJECTIONS
(IMPROVEMENT OF CRYSTALLINE ROCK MASSES BY GROUTING)

Arguelles, H.

International Society of Rock Mechanics, First Congress, Lisbon, 1966, Proceedings, vol.2, p.675-679.
Reviews techniques for measuring the effects of grouting on the mechanical characteristics of foundation rocks and examines results obtained by the treatment of different types of fractures. In French with brief English summary.

CONTROLE DU TRAITEMENT PAR INJECTION DES ROCHES SCHISTEUSES M
(CONTROL OF THE TREATMENT BY INJECTION OF SCHISTS)

Arguelles, H., Bollo, M.F., and Navalong, N.

International Society of Rock Mechanics, 1st Congress, Lisbon, 1966, Proceedings, vol.2, p.625-631.
Effects of grouting performed to improve the rheological characteristics of schists were verified by methods used in Spain. Required characteristics of the rock mass obtained on the basis of correlations between local tests and more general explorations of the seismo-elastic type. Reviews some typical dam foundation projects which are relative to these problems. In French with brief English summary.

SOME NOTES ON THE DESIGN OF GROUTED CURTAINS ON THE BASIS OF M
WATER PRESSURE TESTS

Arhippainen, E.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.137-145.
Discusses difficulties based on the geological conditions in the hard rock which were encountered in using generally accepted criteria in designing grout curtains. These difficulties include interpretation of the water pressure tests and measurement of the real water pressures and the real flow conditions in the fissures of the rock.

CONSOLIDAREA SI IMPERMEABILIZAREA PAMINTURILOR PRIN INJECTARE CU SUBSTANTE DE PRODUCTIE ROMANEASCA (ROMANIAN) (CONSOLIDATION OF SOILS AND MAKING THEM IMPERMEABLE BY GROUTING WITH ROMANIAN MADE CHEMICAL AGENTS) M

Balla, R.J., Antonescu, I., Heitner, A., and Blidaru, M.

Hidrotechnica, vol.18, no.6, p.295-302, 1973.
The results of laboratory and field tests are given in connection with the practical application of such grouting agents as synthetic resins, sodium silicate, and other chemicals.

COMPUTATION OF ANCHORAGES FOR DEEP OCEAN CUTS IN SOIL C, P

Bazant, Z.

Inzenyrske Stavby (Prague), vol.17, no.7/8, p.2829-2893, 1969.
Includes a discussion of the design of anchors produced by cement grouting.

INVESTIGATION OF MUDJACK SOILS P

Benkelman, A.C.

Washington, D.C., Highway Research Board, Proceedings, vol.12, p.352-362, 1932.
Success in raising pavement slabs permanently by the mud-jack process depends to a large degree upon the characteristics of the materials used. The effects of texture, amount of organic material present, amount of cement used and amount of water needed for workability upon the shrinkage properties of the soil appear to be the significant factors.

STABILIZATION AND SEALING OF EARTH STRUCTURES BY MEANS OF GROUTING M

Bethauser, A.

Tiefbau, vol.11, no.4, p.281-283, 1969.
The injection of laitance, synthetic resins, etc., depending on the type of soil, is proposed for the improvement of sealing of earth structures for canals and water courses. The grouting under pressure can be carried out down to certain depths with the injection rod described. Main advantages are: drilling and grouting are carried out with the same linkage, the grouting process is carried on continuously during the drilling, and the rod allows controlled grouting at various depths.

SU ALCUNE APPLICAZIONI DEL PROCEDIMENTI PER IL MIGLIORAMENTO DELLE CARATTERISTICHE DEL TERRENI (IMPROVEMENT OF SOIL PROPERTIES: SOME CASE HISTORIES) M

Bevillacqua, V.

Rivista Italiana Geotecnica, vol.5, no.1/2, p.55-62, 1971.
Selected examples of the use of grouting in treating soils. Methods discussed include subsoil groutings, electro-osmosis, freezing and stabilization. Methods and costs are given and difficulties which were encountered are described.

INJEKTIONEN IM FELS (INJECTIONS IN ROCK) M

Boesch, K.

Schweizerische Bauzeitung, vol.80, no.1, p.8-13, January 4, 1962.
Discusses boring methods for grout holes, grouting materials and instruments and pressure grouting techniques.

STAGE GROUTING PRELOADING OF LARGE PILES ON SAND

Bolognesi, A.J.L., and Moretto, O.

International Conference on Soil Mechanics and Foundation Engineering, 8th, Moscow, August 1973, Proceedings, vol.2.1, p.19-25.
The first part of this paper deals with the preloading by stage grouting technique.

CONTRIBUTION A L'ETUDE DES INJECTIONS DES SABLES TRES FINS PAR LE CEL DE SILICE (CONTRIBUTION TO THE STUDY OF THE INJECTION OF SILICA GEL INTO VERY FINE SAND) C

Bosse, J.

Universite de Nantes, Institut des Sciences de la Nature, Doctoral Thesis, 1972. 91p.
Tells of application of grout to the Beauchamp Sand at the Auber Station along the regional rapid transit network of the Paris Underground Railway RER(RATP). During the construction of the RER Tunnel, new injection and waterproofing methods were used on a large scale, and the results obtained showed their efficiency. The first part of the study describes the state-of-the-art of silica gels and injection methods. The second part deals with the research and development of a means of making the gel visible in order to make possible an investigation of its distribution in the sediments.

COMPACTION GROUTING M

Brown, D.R., and Warner, James

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.99, no.SM8, p.589-601, August 1973, Paper 9908.

Compaction grouting consists of intruding a mass of very thick consistency grout into the soil, thus both displacing and compacting it. Thus, its use is nearly always limited to soils and usually soils of low compaction. Compaction grouting is most commonly used to stabilize the soil under residences and light commercial buildings, however, it has been extensively used to stabilize foundations of larger structures, even including bridges and culverts and the ground under the tips of piles. All types of soil can be improved by compaction grouting, but the effectiveness for a given amount of effort will vary according to soil type and density. The advantages of compaction grouting are minimum disturbance to the structure and surrounding ground during repair, minimum risk during construction, greater economy, flexibility of scope, applicability where the ground-water surface is high and ability to lift settled structures to proper grade. Disadvantages or limitations are: difficulty in analyzing results, limited application at very shallow depth or where lateral restraint is lacking, and, in some cases, cost for deep work. The grout holes are generally predrilled and cased at least to the top of the zone to be improved. An alternate is to set the casing to the competent material and inject grout as it is withdrawn. The grout material most often used consists of fine sand combined with about 12% cement and water to form a very stiff mortar-like mixture. The grout is injected as a homogeneous mass with a distinct interface between the grout and soil. It will tend to move into the weakest zones and the resulting mass may be irregularly shaped.

BODENINJEKTIONSTECHNIK; EINPRESSUNG IN UNTERGRUND UND BAUWERKE M

Cambefort, H.

Wiesbaden, Bauverlag GmbH, 1969, 543p.

Basic requirement of injected substances, different types of injection grouting, theory and principles of injection, conditions necessary for application, experiments that should be carried out, sources of error, techniques of injection, solving problems by methods based on present scientific and technical knowledge and practical examples of the injection techniques are discussed. This is translation into German by Klaus Baek of Cambefort's "Injection des Sols."

DILUTION DES COULIS NEWTONIENS INJECTES DANS LES SOLS PULVERULENTS (DILUTION OF NEWTONIAN GROUT INJECTED INTO POWDERY SOILS) M

Cambefort, H., Gerber, C., Stefan, H., and Berthaud, R.

Genie Civil, vol.42, no.11, p.236-239, June 1, 1965; no.12, p.270-276, June 15, 1965.
Dilution of Newtonian grout injected into powdery soils; flow of grout curtain in its frontal transition zone, where grout was diluted, was experimentally investigated on soil models and sands of various granulometry; conclusions are given regarding injection procedures which resulted in complete filling of interstitial cavities in porous soils.

INJECTION DES SOLS M

Cambefort, H.

Paris, Eyrolles, 1964.
Two volume set on injections in soils. Volume 1 gives principles and methods; volume 2 gives applications. In French.

METHODS OF SOIL STABILIZATION (CHEMICAL, SLURRY TRENCH CONSTRUCTION, ETC.) C

Cambefort, H., and others

International Conference on Soil Mechanics and Foundation Engineering, 8th, Moscow, August 1973, Proceedings, Special Session 7, vol.4.3, p.351-404.
This discussion is limited to problems of chemical grouting, slurry trench walls, and impervious walls. The chemical grouting as it is applied in the Soviet Union and the use of the freezing method are reviewed. The use of grouting in connection with piles is also discussed.

DIE ELEKTROCHEMISCHE BODENVERFESTIGUNG C

Casagrande, L.

Bautechnik, vol.17, no.16, p.228-230, 1939.
Soil consolidation by-the electro-chemical method.

CHEMICAL GROUT CURTAIN STOPS WATERFLOW THROUGH FINE SAND C

Construction Methods and Equipment, vol.48, no.7, p.94-97, July 1966.
Polymer type grout (AM-9) consolidates soil.

CHEMICAL SOIL STABILIZING AND GROUTING C

Public Works, vol.91, no.6, p.146, June 1960.
An entirely new concept of soil stabilization and grouting - the development of a chemical that turns water into a stiff continuous gel in a controlled period of time, has been announced by American Cyanamid Co. It is available as a dry white powder and is applied in a non-viscous solution which will penetrate any mass through which water flows. AM-9 has been successfully used to seal off the flow of underground water into oil wells, drill holes, tunnels, cofferdams, sewer pipe joints, caissons and open excavations, and to seal underground curtain walls in and around dams and dikes. It is particularly effective for solidifying weak, granular soil masses during tunneling operations, the sinking of caissons, and in many types of shafts and excavations in which it is desired to increase the load bearing characteristics of soils. AM-9 in both powder and solution forms, contains acrylamide, a toxic chemical, and prolonged or repeated exposure must be avoided. However, there are no health hazards associated with field applications when used as directed. The chemical may also be mixed with cement, bentonite, sawdust, salts, and thickening agents to modify the properties of the solutions and the resulting gels.

NEW METHOD OF SOIL STABILIZATION M

Czerny, C., and others

Acta Technica, vol.64, no.1-2, p.77-87, 1969.
Problems associated with stabilization of soils with high water content and low cohesion is dealt with; it is shown how difficulties in grouting can be overcome by gaseous processes, where gas rather than fluid is used as reagent substance.

DIE GRUNDUNG VON INDUSTRIE-OBJEKTEN UND WOHNGEBAUDEN MIT HILFE DER BODENVERFESTIGUNG (FOUNDATION OF INDUSTRIAL STRUCTURES AND RESIDENTIAL HOUSES BY SOIL SOLIDIFICATION) C

Cziglina, V.

International Conference on Soil Mechanics and Foundation Engineering, Budapest, 1963 (organized by Hungarian Academy of Sciences), Proceedings, p.375-384.
Describes new soil solidification method which uses carbon dioxide

and water glass as agents. Comparison with other conventional and more expensive methods. Sketches of the use of the rather simple equipment. In German with brief English summary.

STUDIES ON GROUTS FOR TREATMENT OF PERVIOUS SOILS P, M

Datye, K.R.

Indian National Society of Soil Mechanics and Foundation Engineering Journal, vol.4, no.2, p.149-176, April 1965.

Investigations relating to selection of grouts and observation on grouting of sandy beds in the foundations of Mula and Girna earth dams are reported. Laboratory test data on the properties of grouts and observations in the field are presented to indicate the extent of penetration achieved by clay-cement and bentonite-cement grouts at different pressures of injections in the laboratory and by various methods in the field. The minimum cement content needed to get fairly stable grouts is indicated. For clay-cement-bentonite grouts it is seen that the zone of influence at low pressure is very much smaller than the usual spacing of grout holes adopted in practice. High k pressures much in excess of overburden pressure would be necessary to achieve the desired spread of grout, but such pressures would cause cracking of the soil mass; this is not necessarily harmful and may in fact be beneficial as it helps to bring the grout hole spacing within economic limits, especially for sand on the border line of penetrability. A unique feature of the data presented is the observations made on large excavations where the grouted foundation sands were exposed for inspection and the evidence regarding influence of fissuration caused by grouting on the permeability of highly compact time indurated sands and silts which are non-plastic. On the basis of studies on silicates which are commercially available, recommendations are made regarding the desired composition and all characteristics of materials for satisfactory grouting. Results of laboratory tests on grouts prepared with different gelling reagents are also reported with special regard to long-range strength and stability. It is shown that sodium aluminate and ammonium sulphate are preferable to sodium bicarbonate as precipitant, and that the aluminate gel is more susceptible to temperature fluctuations.

GROUTING IN GROUND ENGINEERING C

Dempsey, J.A., and Moller, K.

Ground Engineering, Proceedings of the Conference, Ground Engineering, organized by the Institution of Civil Engineers in London, 16 June 1970, p.3-10.

Grouting has become established in modern ground engineering as a means of improving the ground, either temporarily or permanently,

for constructional purposes. This report outlines its range of applications to problems connected with difficult soils in which the control of ground water is often of prime concern. The relative merits of grouting and diaphragm construction in the formation of dam cut-offs are discussed. Examples are given of recent important works in which grouting played a notable part. A resume is given of the materials used for grouting, which may be classified into suspensions and chemical fluids, many of the latter being available only as proprietary products. The factors which may affect the choice of grouts are indicated. Injection methods, including the use of the driven lance and the sleeved tube, are discussed and some comments on their application are made. Finally, various means of testing the treated ground are given.

THE PERMEABILITY OF SAND STABILIZED WITH A CHEMICAL GROUT C

Dorion, G.H., Burkhard, H., and White, M.L.

American Society for Testing and Materials, Bulletin no.250, p.34-35, December 1960.
In the development of AM-9 chemical grout, the water permeability of grouted sand was measured to get an indication of the general effectiveness of the grout in rendering soils impermeable. The results of experiments designed to measure the Darcy coefficient of permeability for sand treated with AM-9 are given here.

BEITRAG ZUR CHEMISCHEN ERFORSCHUNG UND BEHANDLUNG VON TONBOEDEN C

Endell, K.

Bautechnik, vol.13, p.226, April 1935.
On chemical investigation and treatment of clay soils.

ARTIFICIAL SOIL FREEZING METHOD FOR SUBWAY CONSTRUCTION C

Endo, K.

Civil Engineering in Japan, vol.8, p.103-117, 1969.
The merits and demerits of the soil freezing method are discussed. For cut-offs in the soft alluvial soils of the Tokyo and Osaka area, steel piles or sheet piles, together with chemical injection, and the underground-wall method are generally used.

ANWENDUNG DER ELECTROCHEMISCHEN VERFESTIGUNG AUT SCHWIMMENDEN PFAHLGRUENDUNGEN C

Erlenbach, L.

Bautechnik, vol.14, no.19, p.257-259, 1936.
Report on use of Casagrande electro-chemical process for consolidating clay soils to increase the bearing capacity of piles.

APPLICATIONS OF ELECTROKINETICS IN GROUTING P

Esrig, M.I.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.94, no.SM5, p.1143-1157, September 1968, Paper 6124.
Permeability of soil is increased by factor of 2 or more while electric field is being applied. Reduces time required to introduce grout when pumping at specified pressure. Some recently reported successful applications in Rumania, Israel, United States and Great Britain. Suggests several possible limitations of method.

UNDRAINED STRENGTH OF CHEMICALLY GROUTED SOILS C

Farmer, I.W.

International Association Engineering Geology, International Congress, 2nd, Sao Paulo, Brazil, August 1974, Proceedings, vol.2, theme VI-2, 6p.
The paper describes the results of a series of undrained triaxial tests on sand samples grouted with soft, medium, and stiff chemical grouts.

SETTLEMENT CONTROL FOR SOSMOTRON BASE P

Feld, Jacob

Pan American Conference on Soil Mechanics and Foundation Engineering, 4th, San Juan, P.R., June 1971, Proceedings, vol.2, p.189-195. New York, American Society of Civil Engineers, 1971.
A foundation for a cosmotron settled small amounts, and the use of the facility was interrupted. Correction and control of future settlements required a strengthening of the granular soils, followed by accurate levelling of the supports. Loading tests, grouting operations, and corrective measures for providing control on settlements are described. Permissible tolerances in level are in thousandths of an inch.

THE INVENTION AND DEVELOPMENT OF INJECTION PROCESSES; PART I: 1802-1850 M

Glossop, Rudolph

Geotechnique, vol.10, no.3, p.91-100, September 1960.
Historical review of injection processes development.

THE INVENTION AND DEVELOPMENT OF INJECTION PROCESSES; PART II: 1850-1960 M

Glossop, Rudolph

Geotechnique, vol.11, no.4, p.255-279, December 1961.
The injection process plays a greater part than ever before in engineering practice, and more research and development is going on than at any time in the past. Rock grouting methods are now well established, and it is in alluvial grouting that most interest is shown. Alluvial grouting has also proved useful in tunnel engineering. In open excavation alluvial grouting has proved very successful in sealing coarse alluvium and preventing the flow of water through it on a number of large power stations. As regards the future, it would seem that research is now being concentrated on the question of cheap and mobile grouts which will give strength to the soil as well as reduce its permeability. A great range of substances have been investigated, such as watersoluble thermosetting resins, polyesters, and epoxides, and a number of patents have been taken out. Work has also been done on the yield point and flow properties of grouts, and in particular on the possibility of creep under pressure.

COMPACTION GROUTING TECHNIQUE AND OBSERVATIONS P

Graf, E.D.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.95, no.SM5, p.1151-1158, September 1969, Paper 6766.
Paper presents theory, techniques, equipment, and materials of a pressure grouting technique used for compacting soils and lifting structures. Technique used in compacting sands, silts, unsaturated clays, and dumps, to underpin structures and to lift structures that have suffered differential settlement.

CHEMICAL GROUTING OF SOIL AND ROCK; EARTH CONTROL AND INVESTIGATIONS COURSE AND CONCRETE CONTROL COURSE C

Graham, J.R.

Denver, Colo., U.S. Bureau of Reclamation, 1967.

Gives history of chemical grout studies at the Bureau of Reclamation, present uses of chemical grouts, and some of the important chemical grouting compounds on the market today.

FORMULATION AND APPLICATION OF GROUTS CONTAINING CLAY M

Greenwood, D.A., and Raffle, J.F.

Grouts and Drilling Muds in Engineering Practice, Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institute of Civil Engineers, 1963, ed. by A.D.M. Penman, p.127-130. London, Butterworths, 1963.

BASIC RELATIONSHIPS AFFECTING THE PLANNING OF SINGLE-PHASE CHEMICAL GROUND STABILIZATION C

Greschik, G.

Denver, U.S. Bureau of Reclamation, Translation no.884, December 1972. Translation from Symposium on Protection of Underground Buildings Against Water, Bratislava, Czechoslovakia, p.97-104, September 1972.
Discusses ground stabilization by use of the chemical injection process.

REVIEW OF EXPANSIVE SOILS C

Gromko, G.J.

American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, vol.100, no.GT6, p.667-687, June 1974, Paper 10609.
Chemical stabilization of expansive soils by chemical additives such as lime and cement has been tried for many years with varying degrees of success. Organic chemicals, fly ash, and other compounds show some promise as agents that will reduce heave in expansive type soils. Lime stabilization develops from base exchange and cementation processes between the clay particles and the lime. The primary effect of small lime additions is to decrease significantly the liquid limit, plasticity index, optimum dry density, and swell, and to increase the optimum water content and strength of compressive type clays. Cement stabilization develops from the cementitious links between the calcium silicate and aluminate hydration products and the soil particles. The action of cement on clay minerals is to reduce the liquid limit, plasticity index, and potential volume change, and to increase the shrinkage limit and shear strength.

GROUTING SIMPLY DONE HOLDS RUNNING SAND BEHIND SHEETING

Engineering Record, vol.73, p.157, January 29, 1916.
Grout poured through pipes in rows behind sheet piling to stop sand and water from leaking through. Sand was stiffened enough to require picking for removal.

SAND CONSOLIDATION WITH EPOXY-RESIN SOLUTIONS M

Havenaar, I., and Meijs, F.H.

Journal of the Institute of Petroleum, September 1963.
Describes a process which overcomes sand troubles in producing wells by consolidating the loose sand around the well bore by means of a high-quality epoxy resin. The process leads to consolidated sands of high compressive strength without a significant reduction in permeability.

SODIUM SILICATE STABILIZATION OF SOILS; A REVIEW OF THE LITERATURE C

Hurley, C.H., and Thornburn, T.H.

Urbana, University of Illinois, Soil Mechanics Laboratory, Soil Mechanics Series no.13, Illinois Cooperative Highway Research Program Series 80, 1971.
This report consists of an annotated bibliography and summary review of the important literature on the use of sodium silicates in soil stabilization processes. Annotations are given for approximately 90 articles published between 1931 and 1965. On the basis of these articles, the authors have summarized pertinent information on stabilizer properties, reaction mechanisms, injection methods of soil solidification, properties of stabilizer-soil mixtures, use of sodium silicates as dustproofers and waterproofers and their use as secondary additives with other stabilizers.

USE OF THE RESIN METHOD FOR STABILIZING MADE GROUND WITH A HIGH CONTENT OF ORGANIC MATTER (OPYT PRIMENENIJA SPOSOBA SMOLIZACII DLJA ZAKREPLENIJA NASYPNYCH GRUNTOV S BOLSIM SODERZANIEM ORGANIKI) M

Ibragimov, M.N., Gorlov, V., and Barinov, A.

Soil Mechanics and Foundation Engineering, vol.9, no.3, p.181-183, May-June 1972. (Translation of Osnovaniya, Fundamenty i Mekhanika Gruntov, vol.14, no.3, p.22-23, 1972.)
A description is given of a case where irregular settlement of earth fills, rich in organic matter, produced large deformations of structures founded on them. Field grouting tests were carried out after permeability tests. The grouting effect was investigated in a test pit. The samples showed a compressive strength of 6-8 Kp/cm^2. In Russian.

SOIL STABILIZATION IN THE BUILDING INDUSTRY

Ingles, O.G.

Australia, Commonwealth Scientific and Industrial Research Organization, Soil Mechanics Section, Technical Memorandum no.9, 1969.
A broad outline of the application of soil stabilization in the building industry in Australia. Various types of grouts and limits of their use are presented including a table of applicability.

THE 'JOOSTEN' PROCESS FOR CHEMICAL SOIL SOLIDIFICATION AND SEALING AND ITS DEVELOPMENT FROM 1925 TO DATE C

Joosten, H.J.

N.V. Amsterdamache Ballast Maatschappij, 1954, 46p.

EROSION OF STABILIZED SOIL (AM-9) C

Karol, R.H.

American Cyanamid Co., April 1961, 4p.
Tests of running water as an erosion agent on a soil mass stabilized with AM-9. Tests indicate erosion is an unimportant factor.

USE OF CHEMICAL GROUTS TO SAMPLE SANDS

Karol, R.H.

American Society for Testing and Materials, Special Technical Publication 483, Sampling of Soil and Rock, p.51-59, February 1976.

EXPERIENCE IN GROUTING BASHKIR SOILS WITH UREA-FORMALDEHYDE RESIN C

Korzhenko, L.I., and Mulyukov, E.I.

Soil Mechanics and Foundation Engineering, no.4, p.261-264, July-August 1969. (Translation of Osnovaniya, Fundamenty i Mekhanika Gruntov, no.4, p.23-25, July-August 1969.)
Sand and clay soils in Russia were grouted to determine the effect of using urea-formaldehyde to increase the bearing capacity of the soil in the region surrounding the piles.

GROUTING: CLAY BASED AND CHEMICAL C, P

Leonard, J.T.

Engineer, vol.211, no.5496, p.864-866, 26 May 1961.
Discusses grouting of alluvial deposits by injection of colloidal grout based on clay or straight chemicals.

POSSIBLE APPLICATIONS OF THE INJECTION METHOD IN LOW PERMEABLE SOILS C

Lochte, I.

Bergbauwissenschaften, vol.17, no.8, p.295-299, 1970.
Possible uses and experience with electro-chemical consolidation of soils are discussed. Results of pf tests using the electron microscope, injection of monomeric plastic-solutions into cohesive soils to reduce the swelling of these soils and to improve the mechanical properties are reported.

SCREEN GROUTING OF ALLUVIUM BY THE E.T.F. PROCESS P

Maillard, R., and Serota, S.

Grouts and Drilling Muds in Engineering Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, May 1963, ed. by A.D.M. Penman, p.75-79. London, Butterworths, 1963.
Grout diaphragms using piling to furnish voids for grouting, then extracting the piling.

EFFECT OF CATALYST IN SOIL-RESIN STABILIZATION C

Majumdar, D.K.

American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, vol.101, no.6, p.531-535, June 1975, Paper 11385.
Using soil-resin stabilized samples, experimental curves are obtained showing how unconfined compressive strengths are related to percent stabilizer at different temperatures with different catalysts.

A STUDY OF MUDJACKING OPERATIONS

McKain, A.G.

Roads and Streets, vol.81, no.7, p.48-55, July 1938.
Discusses selection of soil materials suitable for use in mud-jacking operations as well as other aspects of the mud-jacking procedure.

LE INLEZIONI PER IL MIGLIORAMENTO DELLE CARATTERISTICHE DEL TERRENI (GROUTING AS A MEANS OF IMPROVING SOIL PROPERTIES) P

Mercogliano, F.

Rivista Italiana Geotecnica, vol.5, no.1/2, p.44-54, 1971.
Detailed survey of the purpose and methods of grouting soils. Several fundamental conditions are specified: movement and continuity, penetrability, stability, time of grouting, durability, balance of subsoil, expenses, technology, human safety, and working schemes. In Italian.

MINING SUBSIDENCE

Mieville, A.L.

Civil Engineering (London), vol.66, no.782, p.953-963, 1971.
Lack of building land in industrial areas in Britain makes it necessary to construct buildings on mining subsidence areas. Remedial measures for inaccessible workings comprise the construction of concrete columns in the void by grouting through small holes drilled from the surface. The composition of the grout and the strength of columns are given.

IN-PLACE TREATMENT OF FOUNDATION SOILS C

Mitchell, J.K.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.96, no.SM1, p.73-110, January 1970, Paper 7035.
Reviews 7 state-of-the-art methods for treating soils to support structures including mixed-in-place intrusion grouting with chemical stabilizers.

SOIL STABILIZATION WITH CEMENT AND SODIUM ADDITIVES C

Moh, Za-Chieh

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.88, no.SM6, p.81-105, December 1962, Paper 3356.
All types of soils from non-plastic sands to heavier clays can be improved by using small quantities of alkali sodium compounds to form insoluble calcium compounds.

GROUTING INTO SOIL UNDER VACUUM CONDITION P

Morimoto, T., and Mise, T.

International Conference on Soil Mechanics and Foundation Engineering, Budapest, 1963 (organized by Hungarian Academy of Sciences), Proceedings, p.421-428.
Method which facilitates penetration of the grout by utilizing well points to create a vacuum in the soil strata to be stabilized. Field examples with detailed plans of arrangement of equipment.

CHEMICAL STABILIZATION OF SOILS C, M

Morrison, W.R.

Denver, Colo., U.S. Bureau of Reclamation, Report REC-ERC-71-30, June 1971.
Results of laboratory and field tests of several petrochemical, liquid soil stabilizers. A deep penetrating liquid asphalt performed satisfactorily in stabilizing sands around transmission tower sites. A water-base acrylic copolymer provides satisfactory erosion control on canal banks in California.

SOIL STABILIZATION BY CHEMICAL MEANS C

Murray, G.E.

Conference on Soil Stabilization, Massachusetts Institute of Technology, Cambridge, Massachusetts, 18-20 June 1952, Proceedings, p.68-80.
The following aspects of soil stabilization are discussed: (1) The forces operating in a soil system and how they can be altered by the introduction of a stabilizing agent, (2) possible mechanisms through which the stabilizing agent can act to alter the soil properties, (3) the effect of both the soil composition and stabilizer composition on the properties of stabilized soils, (4) methods of formation of stabilizing agents on the soil, and (5) application of such concepts to present and potential stabilization methods.

ACCES ET INTERCOMMUNICATIONS DE LA STATION "AUBER" (PHASE V); TRAITEMENT CONFORTATIF DES SABLES DE BEAUCHAMP PAR INJECTION DE GELS DE SILICE (ACCESS AND INTERCOMMUNICATIONS OF "AUBER" STATION (PHASE V); EFFECTIVE TREATMENT OF BEAUCHAMP SOILS BY GROUTING WITH SILICA GELS) C

Navarro, H., Ottmann, F., and Bosse, J.

Travaux, no.453, p.9-24, December 1972.

AD-A057 831 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 11/2
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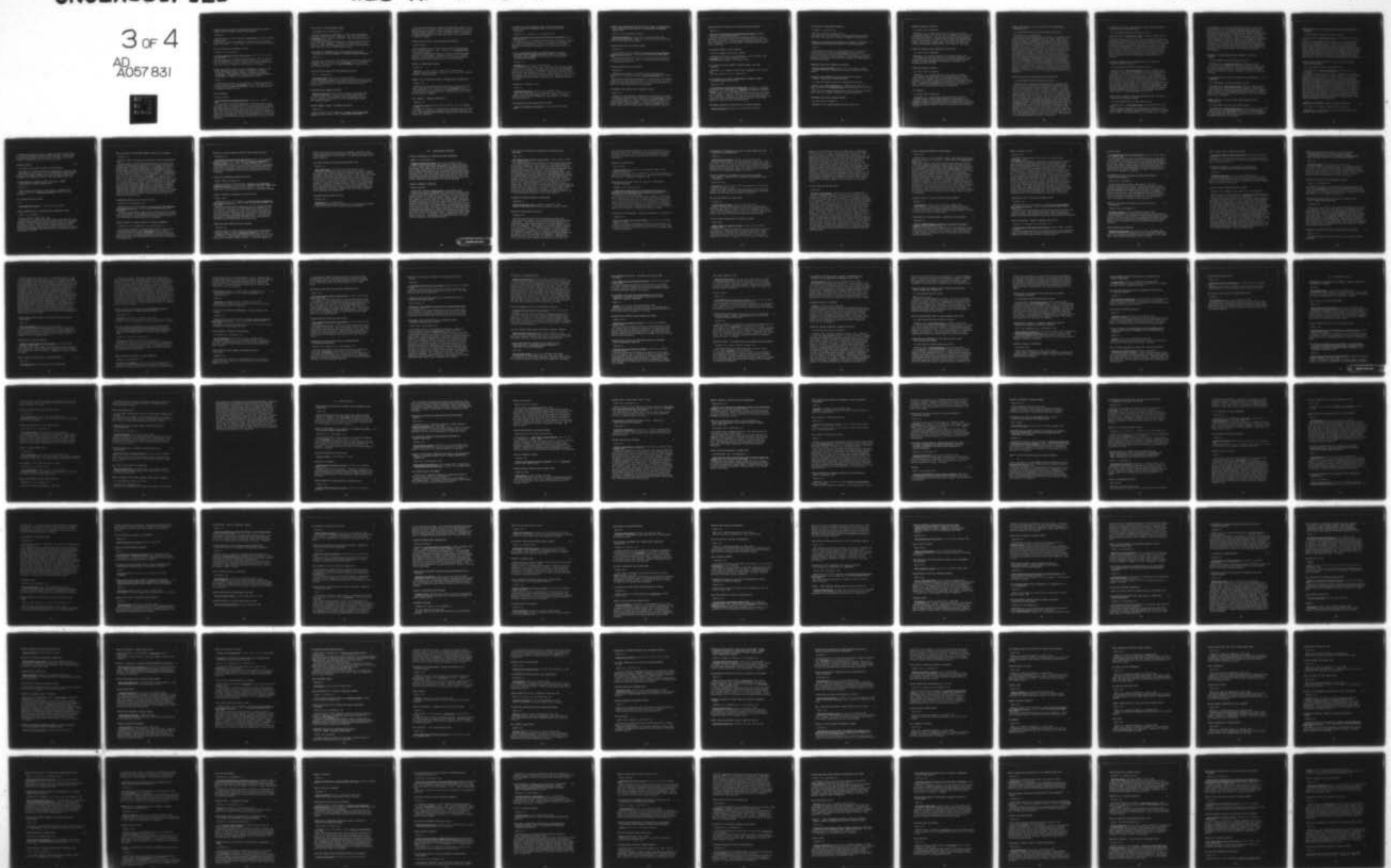

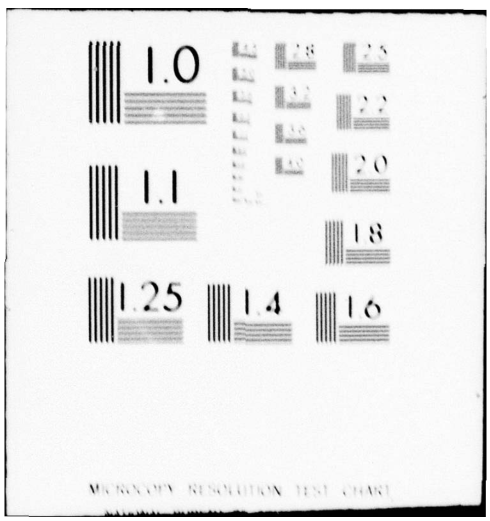
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MICROCOPY RESOLUTION TEST CHART

IMPROVED METHOD OF CONSTRUCTING FOUNDATIONS UNDER WATER BY FORCING CEMENT INTO LOOSE SAND OR GRAVEL BY AIR PRESSURE P

Neukirch, F.

American Society of Civil Engineers, Transactions, vol.29, p.639-643, September 1893.

Dry cement forced by air pressure into saturated sand (quicksand) stopped settlement of a 5-foot sewer. Method used for other structures.

SOIL SOLIDIFICATION BY CHEMICAL INJECTION C

Neumann, H., and Wilkins, L.S.

Civil Engineering and Public Works Review, vol.67, no.791, p.635-636, June 1972.

Discusses the use of chemical solidification of soils for underpinning the subbasement of a new building in Mannheim, West Germany. After lowering the water table, silicates were injected through small tubes into the soil, using the Joosten Process of grouting.

DRAINAGE AND STABILIZATION OF THE SOIL SURROUNDING A TUNNEL OF THE PARIS UNDERGROUND RAILWAY BY MEANS OF SYSTEMATIC INJECTIONS OF CHEMICAL PRODUCTS UNDER PRESSURE, IN PRESENCE OF SELENITIC GROUND-WATER (ETANCHEMENT ET STABILIZATION DU TERRAIN ENCAISSANT UN SOUTERRAIN DU CHEMIN DE FER METROPOLITAIN DE PARIS) C

Noblet, F.

International Conference on Soil Mechanics and Foundation Engineering, 2nd, Rotterdam, 1948, Proceedings, vol.5, p.269, Session IX, c13.

One-page English summary of the French report. Discusses grouting of underground railway in Paris.

INSITU ANCHORING P

Nordin, Per-Olof

Rock Mechanics and Engineering Geology, vol.4, no.1, p.25-36, 1966.

A hollow anchor rod with an anchor shoe is sunk by means of a rock drill into rock or earth with the use of rotation and water flushing. The cement slurry is injected into the rock via the hollow anchor rod. The hollow anchor rod serves both as the drill steel and injection tube. The rock can be consolidated directly by injection through the anchor rod. The anchor is usually placed approximately ten feet into sound rock and then grouted. In the event unsound rock is encountered, the rock is consolidated by grouting, redrilled and the anchor is then grouted in.

A CASE STUDY OF THE BAUER EARTH ANCHOR P

Oosterbaan, M.D., and Gifford, D.G.

Specialty Conference on Performance of Earth and Earth-Supported Structures, Purdue University, Lafayette, Ind., June 11-14, 1972, Proceedings, vol.1, part 2, p.1391-1393. New York, American Society of Civil Engineers, 1972.
This paper describes some observations of the performance of Bauer type earth anchor tiebacks. A total of 328 tiebacks were used to support an H-pile and wood-lagging wall for a deep excavation made in dense sands and clay till soils in Boston, Mass.

A NEW METHOD OF IMPERMEABILIZATION AND IMPROVING THE PHYSICAL PROPERTIES OF PERVIOUS SUBSOILS BY INJECTING BITUMINOUS EMULSIONS M

Pfeiffer, J.P.

International Conference on Soil Mechanics and Foundation Engineering, Cambridge, Mass., June 22-26, 1936, Proceedings, vol.1, p.263-266.
Examples: Sealing bottom of leaking building pit; application at Assint Barrage on Nile.

SOLIDIFICATION OF SANDS WITH UREA-FORMALDEHYDE RESINS C

Plch, J., and Gresa, J.

Inzenyrske Stavby, vol.17, no.3, p.116-119, 1969.
Chief properties, preparation for grouting and significance of macromolecular grouting materials. Rheological properties of the grout and results of laboratory and field grouting tests and principles for practical use.

PRESSURIZED GROUT ANCHORS TIE-BACKS P

Western Construction, vol.45, no.11, p.33-34, 46, November 1970.
Savings on high cost of internal bracing for bulkhead support in poor soils may follow successful use of pressurized grout for tie-back anchorage and adoption of a new rod installation method that eliminates augers.

GROUTING MANMADE ISLANDS - CHESAPEAKE BAY BRIDGE P

Prugh, B.J.

American Society of Civil Engineers, Journal of the Construction Division, vol.92, no.CO1, p.37-51, January 1966, Paper 4621.

The man-made islands form a transition from bridge to tunnel. The islands are 1500 ft along the line of the tunnel, and 230 ft wide each. The grouting was necessary to allow successful excavation of the ventilation building areas on 3 of the 4 man-made islands. Grouting was performed through standard 2" steel pipes driven into position with a standard air hammer.

BONDING SOIL WITH RESIN (TALAJSZILARDITAS MUANYAGGAL) C, M

Regele, Zoltan

Charlottesville, Va., U.S. Army Foreign Science and Technology Center, FSTC-HT-23-215-70, 1970. Translated from Muanyag Es Gumi, no.6, p.276-280, 1969.
Discusses research efforts aimed at utilization of various amino plastics for soil bonding. Carbamide resin was found to be most suitable. Research indicated that PX-4 due to excellent synthetic characteristics should be popular for soil bonding purposes.

GROUTING OF PRESTRESSED CONCRETE P

Rhodes, B.

Surveyor, vol.121, no.3673, p.1313-1315, 27 October 1962.
Objects of grouting, mixing techniques, ducts for grouting, pumping pressure; grouting equipment.

CHEMICAL SOIL SOLIDIFICATION WORK IN CONSTRUCTION AND EMERGENCIES C

Riedel, C.M.

Conference on Soil Stabilization, Massachusetts Institute of Technology, Cambridge, Mass., 18-20 June 1952, Proceedings, p.68-77.
The Joosten Process is discussed with applications of the injection grouting method to construction work. Limitations and costs of the process are also discussed.

SAND CONTROL-3. CHEMICAL CONSOLIDATION C, M

Rodgers, E.B.

Oil and Gas Journal, vol.69, no.46, p.152-154, 156, 161, November 15, 1971.
Discusses the injection of liquid organic substances into the formation, where they harden or polymerize by either preactivation or in situ. Resin characteristics, process characteristics, and application methods are discussed.

UTILISATION DE COULIS RADIOACTIF DANS L'ETUDE DES INJECTIONS DE SOL (THE USE OF RADIOACTIVE GROUT IN THE STUDY OF SOIL INJECTIONS)

Rousselin, R.J., Gauthier, C., and Poupelloz, B.

Bulletin de Liaison des Laboratoires des Ponts et Chaussees, no.73, p.101-112, 1974.
Clay-cement grouts are marked with Indium 113m, which must be detected as a radioactive element in boreholes. By means of this method, the exact position and thickness of the levels injected can be given together with distances of propagation in the horizontal plane. In French.

RISSE IN EINEM GEWOLBE INFOLGE UNTERGRUNDBEWEGUNGEN UND DEREN SANIERUNG MITTELS KUNSTHARZINJEKTIONEN (CRACKS IN AN ARCH AS A RESULT OF SUBSOIL MOVEMENTS, AND THE REPAIR OF THESE BY MEANS OF SYNTHETIC RESIN GROUTS) M

Rudolph, C.L.

Bauingenieur, vol.46, no.2, p.45-49, 1971.
An arched structure having a clear span of 6 m had to be built under a main low-cost road in an area where there was a motorway embankment section up to 15 m high. The foundation was built with Franki displacement piles having a diameter of 500 mm. Raking piles were put at the end portals. The piles were horizontal to the limestone. After the work was finished there were cracks in the structure. The causes of the settlements and cracks and the elimination of the damage are described. In German.

TECHNIQUE OF INJECTIONS IN SOIL C

Ruppel, G.

Bergbauwissenschaften, vol.17, no.8, p.285-290, 1970.
Gives short description of soil injections with chemicals for non-cohesive soils and illustrated by practical examples. Proposes a method for improving the technological characteristics of cohesive, non-injectable soil.

SAND CONSOLIDATION WITH EPOXY-RESIN SOLUTIONS C

Journal of Institute of Petroleum, vol.49, p.392-397, December 1963.

ANWENDUNG DER BODENVERFESTIGUNG BEIM BAU DER S-BAHN IN FRANKFURT/MAIN (SOIL STABILIZATION WORKS APPLIED IN CONSTRUCTION OF FRANKFURT TRANSIT LINE)

Schultz, E.W., and Dintzner, Joseph

Bautechnik (Ausgabe B), vol.52, no.2, p.37-42, February 1975.
Describes the grouting of sandy soils encountered near the railroad station of Frankfurt, West Germany.

MIXING-IN-PLACE SOIL AND PORTLAND CEMENT P

Sherard, J.L.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.95, no.SM6, p.1357-1363, 1969, Paper 6909.
Construction methods can be found to mix portland cement grout and soil in place below ground. There can be applications in the field of underground construction.

PORTABLE EQUIPMENT FOR SOIL GROUTING C

Skarajew, W.

Commonwealth Scientific and Industrial Research Organization (Australia), Soil Mechanics Section, Technical Memorandum no.8, 1969, 11p.
Describes the design and development of a portable unit for injecting chemical grouts under pressure in slurry or in liquid form into soils. Operations with grouting pressures up to 100 psi at depths from two to eight feet proved successful with this equipment.

THE CHROME-LIGNIN PROCESS AND ION EXCHANGE STUDIES C

Smith, J.C.

Conference on Soil Mechanics Stabilization, Massachusetts Institute of Technology, Cambridge, Mass., 18-20 June 1952, Proceedings, p.81-83.
In the development of a soil solidification agent for army use, the chrome-lignin process was studied. It was found that mixtures of sulfite wastes, sodium bichromate, or potassium bichromate will stabilize a wide variety of soils, using a rapid controllable reaction.

FOUNDATION CURTAIN GROUTING EVALUATED WITH UNIT TAKE CONCEPT P

Smith, T.J.

Bulletin of the Association of Engineering Geologists (London), vol.5, no.2, p.137-154, Fall 1968.
Sandstone and shale with soft shaly seams were grouted. After grouting, drain and weep holes were drilled and were dried, proving the curtain effective. Rock had numerous joints and fractures. Grout slurry composed of Type II PC and water. All holes pressure tested prior to grouting.

CLAY-CEMENT MIXTURES IN SOIL INJECTION P

Societe de Sondages, Injections, Forages

International Conference on Soil Mechanics, 2nd, Rotterdam, 1948, Proceedings, vol.5, p.272, Session IX, c16.
One-page English summary of the French report.

SOIL STABILIZATION WITH ASPHALT, PORTLAND CEMENT, LIME, AND CHEMICALS P

Washington, D.C., Highway Research Board, Bulletin no.241, February 1960.
Contains six papers on soil stabilization.

NEW ACHIEVEMENTS IN CHEMICAL STRENGTHENING OF GROUND (NOVOE V CHIMICESKOM ZAKREPLENIL GRUNTOV) C

Sokolovic, V.E.

Soil Mechanics and Foundation Engineering, vol.8, no.2, p.114-118, March-April 1971. (Translation of Osnovaniya, Fundamenty i Mekhanika Gruntov, no.2, p.23-25, March-April 1971.)
Surveys recent work of the Scientific Research Institute for Foundations in Moscow. Grouting of sand and loess soil with gas and silicate is described. Principles of chemical reactions, advantages of new methods and brief qualitative and quantitative data on the results achieved are given for each method discussed.

SUB-SURFACE GROUTING; 20 MILLION SQ FT OF LEAKING LIMESTONE

Construction World, vol.16, no.4, p.30-34, February 1961.

SOIL MECHANICS IN ENGINEERING PRACTICE P

Terzaghi, K., and Peck, R.B.

New York, John Wiley and Sons, 1948.
This basic book on soil mechanics contains several short sections discussing cement grouting as applied to highways and foundations.

CONTROLE DE LA QUALITE DE L'INJECTION PAR LA METHODE D' "INFUSION" P
(VERIFICATION OF INJECTION BY MEANS OF THE "POURING METHOD")

Tkany, Z.

International Association of Engineering Geologists, First International Congress, Paris, 1970, Proceedings, vol.2, p.826-835.
Describes practical application of the pouring method to control the success of injection in check boreholes. The proposed device makes it possible to continuously and automatically measure the sinking speed of the boundary level.

UNDERGROUND WATER FLOW STOPPED BY NEW METHOD M

Western Construction News, vol.24, no.4, p.146, April 15, 1949.
Describes formation of underground barriers by Shellperm Grouting Process.

CRITERIA OF EFFECTIVENESS OF SOIL STABILIZATION BY GROUTING M
(KRITERIA EFEKTIVNOST; SPEVNOVANIA ZEMIN)

U.S. Army Cold Regions Research and Engineering Laboratory

Hanover, N.H., Draft Translation no. CRREL-TL-578, January 1977. (Draft translation of Inzenyrske Stavby (Czechoslovakia), no.1, p.29-32, 1974.)
This article by Jaromir Plch presents a critical analysis of factors which affect the economical aspects of grouting (injection).

ENGINEERING AND DESIGN; CHEMICAL GROUTING C

U.S. Army. Corps of Engineers

Washington, D.C., Engineer Manual EM 1110-2-3504, 1973.

FOUNDATION GROUTING; EQUIPMENT P

U.S. Army. Corps of Engineers

Washington, D.C., Engineer Manual EM 1110-2-3502, April 1948.
Preliminary manual. The various types of equipment used in grouting operations are discussed. The two types of drills used, percussion drills and rotary drills, along with the advantages and disadvantages of each, are discussed. The use of mixers, sumps, and pumps are discussed. Water meters, pressure gages, valves for grout lines, and foundation displacement indicators are also treated in this manual.

FOUNDATION GROUTING; FIELD TECHNIQUE AND INSPECTION C, P

U.S. Army. Corps of Engineers

Washington, D.C., Engineer Manual EM 1110-2-3503, August 1963.
This manual discusses the principles of foundation grouting. Drilling operations are discussed and grouting means and methods are explained, including arrangement and operation of equipment, hole cleaning and grout injection.

FOUNDATION GROUTING; PLANNING C, P

U.S. Army. Corps of Engineers

Washington, D.C., Engineer Manual EM 1110-2-3501, July 1966.
This manual covers all aspects of grouting planning, including various types of treatment and grouting methods, materials, and processes. The equipment required for drilling and grouting are discussed, including the advantages and limitations of each type of equipment. Criteria and recommendations are presented which should be helpful in field operations of drilling and grouting.

SOIL SAMPLING C, P

U.S. Army. Corps of Engineers

Washington, D.C., Engineer Manual EM 1110-2-1907, March 1972.
Contains section on backfilling boreholes and excavations. All boreholes located on the land side of levees, downstream of dams and embankments should be completely grouted. Describes injection grouting process of borings by means of a grout pipe inserted to the bottom of the hole.

INITIAL FIELD TESTS OF CALCIUM ACRYLATE AS A SOIL SOLIDIFIER; MEMORANDUM REPORT C

U.S. Army Engineer Research and Development Laboratories

Ft. Belvoir, Va., January 1952.
Calcium acrylate test conditions and procedures - equipment, preparation of test lanes, construction of test lanes, traffic tests, product evaluation. Discussion: laboratory tests, test lane construction, traffic tests, equipment performance, laboratory-field correlations, limitations and significance of these tests, improved equipment plan. It is concluded that: (a) Only a fraction of the potential performance of calcium acrylate treated soil has resulted from field test lanes placed to date; (b) even the relatively poor calcium acrylate treated soil products now obtained in field tests are operationally useful for military purposes; (c) attainable improvements in performance of presently available modified equipment will increase the military utility of calcium acrylate treated soil; (d) sufficient field equipment requirements and techniques have been established to guide the development of an experimental item of soil solidification equipment designed to overcome known deficiencies of presently available equipment; (e) the full military utility of calcium acrylate as a soil solidifier cannot be assessed without development of new equipment for mixing and placing calcium acrylate treated soils; (f) development of new equipment designed to assess the full military utility of calcium acrylate treated soil is warranted.

INVESTIGATION OF SOIL STABILIZATION WITH VINSOL RESIN C

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Memorandum no.196-1, November 1942.
Report of an investigation of stabilization of soils with Vinsol resin, a resinous water-repellent substance obtained as a product from the distillation of turpentine from pine stumps. Included are the results of laboratory tests conducted on seven different types of soil, treated and untreated. The results of the laboratory investigation indicate that the types of soil that can be satisfactorily stabilized with Vinsol are limited. Thus, it was found that a sandy silt, silty sand, clay silt, silty clay, and clay sand could be improved considerably by treatment with Vinsol in the proper amounts, but that a silt and a clay could not be stabilized for the range of treatments studied. The unconfined compressive strengths of the raw and Vinsol-treated soils are for all practical purposes the same condition of test water content. The action of the Vinsol slurry appears to be one in which the substance acts as a seal, thus causing the rise of capillary water to be retarded somewhat, rather than as an agent reducing capillary rise by increasing the angle of contact of the meniscus between it and the soil grains. The permanency of the stabilizing effect of Vinsol is not known.

NEW APPLICATIONS OF GROUT AND CONCRETE AS SHOCK IMPEDANCE MATCHING MATERIALS FOR GEOLOGIC FORMATIONS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.C-72-10, CTIAC-5, April 1972.

New applications of grout and concrete with supporting studies and experimental techniques are reported herein in a general sense. These new applications are in support of underground nuclear weapons testing. Grouts and concretes are designed and tested to respond to a high-pressure shock environment in the same manner as the in-situ formation. This is quantitatively described by the equation of state of the materials at high pressures and the constitutive relations at lower stresses. Several typical matches in the equation-of-state plane are presented, which represent work done in support of the various weapons test events. This paper was prepared by D.L. Ainsworth.

PRELIMINARY INVESTIGATION OF CHROME-LIGNIN AS A STABILIZING AGENT IN VICKSBURG LOESS SOIL C

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.3-145, September 1955.

This report describes a preliminary laboratory investigation (by G.R. Kozan) to determine the suitability of chrome-lignin as a stabilizing agent for Vicksburg loess soil. It is concluded from this study that: (a) the stabilizing ability demonstrated by the chrome-lignin used in this investigation indicates that it is chemically satisfactory for further use, having suffered little or no loss of potency during storage or reprocessing; (b) beneficial results were obtained in loess treated with 7.5 percent chrome-lignin; particularly rewet strengths definitely indicate an improvement in the strength properties of loess soil. It is recommended that further tests be conducted with loess soil to study the full potential of chrome-lignin as a stabilizing agent for this soil.

PROJECT DUGOUT; CONCRETE, GROUT AND SHOTCRETE SUPPORT, AND DESIGN AND POSTSHOT EVALUATION OF STEM P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-729, PNE 610 F, April 1965.

Project DUGOUT consisted of the simultaneous detonation of five 20-ton, chemical, row-charge explosives in hard, dry rock at a scaled depth of burst. The primary purpose of the project was to increase

the knowledge of row cratering dimensions in hard, dry rock. This report describes the following work performed for the project by personnel of the U.S. Army Engineer Waterways Experiment Station: (a) the design and placement of grout mixtures used in grouting satellite holes surrounding the anticipated trench; (b) the design and supervision of the placement of a shotcrete mixture used in lining the walls of each of the shot cavities; (c) the design and supervision of the placement of a shotcrete mixture used in lining the walls of each of the shot cavities; (d) the design and supervision of the placement of a concrete mixture used in stemming the access holes to each of the shot cavities; (e) the design of the stem configuration for each of the five shot holes, and (f) postshot evaluation of stem design and survey of stem ejecta. This report was prepared by K.L. Saucier.

RESTORATION OF LANDING-MAT-SURFACED SUBGRADES BY GROUTING METHODS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Instruction Report no.S-70-3, June 1970.
This report by C.D. Burns and V.C. Barber provides instruction in the use of portland cement grouts for grouting beneath landing mats as a method of subgrade repair. The report includes exact guidelines for preparation of grouts, equipment to be used, and grouting technique.

SOIL STABILIZATION FOR ROADS AND AIRFIELDS IN THE THEATER OF OPERATIONS C, P, M

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.S-74-23, September 1974.
This study was by W.N. Brabston and G.M. Hammitt. The objective of this study was to develop a design system for the use of chemically stabilized soil layers in pavement systems in the theater of operations. Stabilization with only portland cement, lime, and bituminous materials was considered.

SUMMARY REVIEW OF LIGNIN AND CHROME-LIGNIN PROCESS FOR SOIL STABILIZATION C

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.3-122, Report 1, April 1955.
This review by G.R. Kozan summarizes briefly the investigations to date of lignin and chrome-lignin processes for soil stabilization. The capabilities and limitations of lignin agents as well as major equipment deficiencies are discussed.

SUMMARY REVIEWS OF SOIL STABILIZATION PROCESSES; CALCIUM ACRYLATE TREATMENT C

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.3-122, Report 2, January 1956.

Calcium acrylate monomer, when added to a soil in the presence of water and an appropriate catalyst, polymerizes, holding the soil grains in a cross-lined network of bonds. Data shows that good stabilization can be achieved by this process on a wide range of soils. A soil stabilized in this manner is weakest and most flexible at high water contents. Large-scale tests indicate that the limitations of presently available construction equipment reduce the effectiveness of the chemical in field treatment. However, the results are considered sufficiently promising to warrant further study of stabilizers of this type. This report was prepared by J.K. Mitchell.

TESTS OF SANDED GROUTS; EFFECTS OF FLY ASH IN GROUTING COARSE SANDS AND FINE GRAVELS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Memorandum no.6-419, Report no.5, April 1963.

Information was desired by the Corps of Engineers as to whether a fly ash with a carbon content in excess of specification limits would measurably affect the quality of grout in which it is used, and whether a grout mixture of water, cement, and fly ash would more effectively penetrate by pump injection the voids formed by granular materials than normal neat cement grout (without fly ash) when the fly ash has an amount of material retained on the no.325 sieve in excess of that permitted by current specifications. The results of the two studies indicated that: (a) an addition of 25% fly ash to a portland-cement grout produced the optimum fly ash grout mixture, (b) the use of a fly ash with a carbon content 8.13% in excess of specifications did not appear to affect the quality of the grout, and (c) the fly ash mixture and the mixture containing no fly ash exhibited essentially the same penetration characteristics. This report was prepared by R.A. Bendineli.

DEWATERING AND GROUNDWATER CONTROL FOR DEEP EXCAVATIONS C, P

U.S. Depts. of the Army, the Navy, and the Air Force

Washington, D.C., Army Technical Manual 5-818-5; NAVFAC P-418; AFM 88-5, Chap.6, April 1971.

This manual contains a section on cement and chemical grouts that are used in dewatering and pressure relief systems. A cutoff around an excavation in porous soils or rocks can be created by injecting cement or chemical grout into the voids of the soil.

MATERIALS TESTING P, M

U.S. Depts. of the Army, the Navy, and the Air Force

Washington D.C. Technical Manual TM 5-530/AFM 88-51, February 1966. This manual contains section on soil stabilization through cementing action of soil-cement treatment, soil-lime treatment, lime-fly ash treatment, and bituminous treatment (including asphalts and tars).

LA STABILISATION AU CIMENT DE DIVERS SOLS BELGES (CEMENT STABILIZATION OF VARIOUS BELGIAN SOILS) P

Van Ael, P.

Centre National de Recherches Scientifique et Techniques Pour l'Industrie Cimentiere, Rapport de Recherche RR CRIC 39-f, 1974. In French.

SOIL STABILIZATION WITH CEMENT P

Vari

Royal Engineers' Journal, vol.70, no.1, p.9-16, 1956.

TESNENI ZAKLADOVYCH PUD (STABILIZATION OF FOUNDATIONS SOILS) P

Verfel, J., and Tkany, Z.

Prague, SNTL Publ. House, 1974, 318p. The first part of the book deals with boring of grouting bore holes, equipment and procedures used in water pressure tests and in grouting, evaluation of water pressure tests and grouting tests, and designs of grouting curtains. The second part contains chapters on soil grouting, grouting procedures, types of grouts, bore holes for grouting, grouting equipment, grouting techniques, test grouting and control of grouting. In Czech.

THE APPLICATION OF POLYURETHANE FOAMED PLASTIC IN SOIL GROUTING C

Vinson, T.S.

Berkeley, Calif., University of California, Doctoral Dissertation, 1970.

The main purpose of this research program was to develop a grout system that would expand in the voids of a soil mass, increase its strength, and decrease its permeability. Accordingly, the use of a foamed plastic as a chemical grout has been investigated. Such a material might satisfy the requirements of a potential lunar grout. It was on this basis that the research was initiated. The emphasis in this dissertation, however, is on the development of a foamed plastic grout for use in the terrestrial environment. In a broad sense, the scope of this thesis is from the development of a chemical grout system from a theoretical analysis of the chemistry of the grout material to the design of a suitable system and evaluation of this system in a simulated field application. Topics covered are soil grouting practices and technology, foamed plastic as soil grouts, chemistry and properties of urethane foamed plastics, development of urethane chemical grout systems, strength and permeability of soil masses stabilized with urethane foamed plastic, economic analysis of urethane foamed plastic chemical systems and anticipated field grouting problems, and foamed plastic chemical systems research for lunar soil stabilization applications.

POLYURETHANE FOAMED PLASTICS IN SOIL GROUTING C

Vinson, T.S., and Mitchell, J.K.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.98, no.SM6, p.579-602, June 1972, Paper 8947.

Injection of polyurethane foamed plastic systems resulted in significant strengthening and the impermeabilization of both dry and saturated granular soils. Six systems were developed satisfying seven criteria established to measure stabilizer suitability.

CURRENT PROBLEMS OF CHEMICAL GROUTING OF SABULOUS FORMATIONS C

Voronkevich, S.D., Evdokimova, L.A., and Morozov, S.S.

International Association of Engineering Geologists, First International Congress, Paris, 1970, Proceedings, vol.1, p.601-615.

Describes a method of chemical grouting with sodium silicate and carbonic acid gas. The mineral composition of the sand grains and their surface conditions determines the effectiveness of consolidation and waterproofing.

EXPERIENCE IN USING CHEMICAL METHODS TO SECURE SLOPE STABILITY C

Vulotskoi, D.V.

Soil Mechanics and Foundation Engineering, vol.11, no.5, p.286-289, September-October, 1974. (Translated from Osnovaniya Fundamenty i Mekhanika Gruntov, no.5, p.9-11, September-October, 1974.)

Experience with correction of soil sliding on slopes of embankments using chemical injections. Some practical cases are described, where sliding slopes have been stabilized by grouting during which stiff elements in the embankment were arrested, reaching below the surface of sliding.

PLANNING AND PERFORMING COMPACTION GROUTING P

Warner, James, and Brown, D.R.

American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, vol.100, no.GT6, p.653-666, June 1974, Paper 10606.

The use of the compaction grouting technique is discussed. The primary use of this technique is the correction of settlement problems.

STRENGTH PROPERTIES OF CHEMICALLY SOLIDIFIED SOILS C

Warner, James

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.98, no.SM11, p.1163-1185, November 1972, Paper 9332.

Though many chemical grout systems are used for strength increase, as well as water control, the requirements differ fundamentally for each purpose. The formation of soft flexible gels and the ability to be used with very short gel times are frequently advantageous in water control work. Conversely, hard rigid gels and long gel times are often desirable in strengthening applications. The particular advantages of acrylamide grout, polyphenol resin, resin emulsions, and sodium silicate base grouts are all discussed.

CONTROLLING CANAL SEEPAGE WITH SOIL SEALANTS M

Willson, R.J.

American Society of Civil Engineers, Water Resources Engineering Conference, Denver, Colorado, Conference Preprint 335, May 1966.

Seepage lanes from canals and laterals can be reduced by the use of soil sealants. Cationic asphalt emulsion was injected into the subsurface by a specially developed machine. A continuous membrane of

asphalt emulsion was injected into the subgrade. The goal of this project was primarily the development of an experimental machine which could possibly be used on large canals. No results were given on the asphalt emulsion.

LIME SLURRY PRESSURE INJECTION TAMES EXPANSIVE CLAYS M

Wright, P.J.

Civil Engineering, vol.43, no.10, p.42-45, October 1973.
Presents a promising and relatively inexpensive solution to many of the unstable-soil problems--lime slurry pressure injection. In this technique, a lime slurry is pumped into the soil under pressure, forming a network of interconnecting, sheetlike seams. These seams act as moisture barriers, preventing the movement of moisture either into or out of the soil. Lime slurry pressure injection is an economical way to deep treat foundation soils in-place to reduce their volume change potential. Because of equipment mobility, LSPI is economically feasible for virtually any size project, from a single-family house to a large commercial structure. Other applications include stabilization of railroad beds and streets, runways, levees and slopes, swimming pools, pipelines, and parking lots.

INJECTIONS INTO ROCK AND LOOSE SOIL P

Zmarzly, H.R.

Monierbauer, no.3, p.18-25, 1972.
Describes injection methods performed by the firm Beton-und Stahlbau to improve the subsoil and the sealing against groundwater.

VII. - MISCELLANEOUS STRUCTURES

A STUDY OF ANCHORAGES FOR TRANSMISSION TOWER FOUNDATIONS

Adams, J.I., and Kylm, T.W.

Canadian Geotechnical Journal, vol.9, no.1, p.89-104, 1972.

A number of uplift tests have been conducted on anchors proposed for use to support high-voltage transmission line towers both for the conventional four-legged structure and for the guyed-type structure with a single central footing. The test installation included both power installed multi-helix anchors and grouted anchors with a single reinforcing rod. The grouted anchor tests were analyzed using either frictional or adhesive bond theory depending on the soil type. The results indicate that the theories using conventional soil properties provide reasonable design parameters for initial planning.

ASPHALT IN HYDRAULIC STRUCTURES M

Asphalt Institute

College Park, Maryland, Manual Series no.12, November 1961.

Grouting with asphaltic materials is a technique for making a stone or rock structure more effective and easier to construct and maintain. Grouting consists of filling up the interstices in a stone structure with a very hot rich mixture of asphalt, cement, mineral filler, and fine aggregate, placed or poured in a near liquid state. The modern technique of grouting with asphaltic materials was initially used on European installations early in the 1930's. The first large scale construction of this type in the United States was the Galveston, Texas Jetty, started in 1935. The asphalt content and elevated temperatures of grouting mixes insure that they can be poured or flowed into place. Placing such a liquid mix on a surface above water may be done by use of a steel trough or by dam shell bucket. In grouting a large rubble-mound structure, it is important to get a maximum penetration of the mix into the voids. The grouting of a slope facing (as on an earth dike) of riprap is a much simpler operation.

USING QUICKSETTING MORTAR FOR MECHANICALLY JOINTING VERY WET BRICKWORK M

Ayres, D.J.

Civil Engineering and Public Works Review, vol.52, no.617, p.1264-1265, November 1957.
Since 1952 when mechanical jointing of brickwork was first developed on the Western Region of British Railways, a considerable amount of work has been undertaken. Other regions have also taken up the use of this method. It can be used in all cases where hand jointing would otherwise be applied, and is quicker, more efficient, permits greater quality control, and requires only semi-skilled labor. Very wet brickwork has so far been hand-jointed by preparing normal mortar and incorporating proprietary admixtures, although mechanical jointing is quite suitable for brickwork which is merely wet, with neither running water on the surface nor seepage from the lining. The normal method of mechanical jointing involves the production of an aerated mortar which is applied pneumatically from a pressure pot to a special gun. About 20 different chemical mixtures were tried before it became obvious that only those of the sodium silicate family produce the required swift setting effect on the mortar. From a series of tests it was found that a high rate of increase of strength as well as swiftness of set was obtained by increasing (a) the concentration and (b) the sodium-silicon molecular ratio of the chemical.

TECHNIQUE OF PRESSURE GROUTING OF FOUNDATIONS P

Beanfield, R.

Western Construction News, p.634-638, October 10, 1928.
Resume of operations, grout mixtures, pressure, and air volume.

GROUTING OF PRESTRESSED CABLE DUCTS P

Boardman, V.R.

South African Prestressed Concrete Development Group, 1959.
Many grouts were found to have satisfactory properties during this investigation. Hand-mixing of grouts should not be imployed as it produces grouts which bleed excessively. Colloidal mixing for 3 to 5 min is recommended. Longer mixing at high speed should be avoided as it reduces fluidity, but hand-stirring can be resorted to while waiting to inject the grout. The flow funnel is a sound apparatus for determining the suitability of a grout for injection pumping. The addition of aluminum filings is desirable as this gives good bond and tends to drive out water that has segregated. Neat portland cements were found to be suitable, and unless it is desired to reduce cost because large quantities of grout are to be used, it is

felt that other materials should be left out for simplification on the construction site. Teams doing the grouting work should be well trained to ensure that they adopt the best procedures of batching and mixing the grout and are conversant with the correct methods of injecting it.

BENTONITE IN CONSTRUCTION M

Boyes, R.G.H.

Contract Journal, vol.232, no.4722, p.865-866, 1969; vol.233, no.4723, p.29-30, 1970.
Describes bentonite, and its preparation. Flow characteristics of a bentonite water-mixture are also given. Sands and gravels are grouted using bentonite or bentonite cement mixtures.

INVESTIGATIONS INTO SOME ASPECTS OF INJECTING IN PRESTRESSED CONCRETE STRUCTURES P

Bulgakov, V.S., and Matkov, N.D.

RILEM (Reunion Internationale des Laboratoires d'Essais et de Recherches sur les Materiaux et les Constructions) Bulletin no. 13, new series, p.29-37, December 1961.
On the basis of the investigations on the properties of grouts and their injection into ducts, the following conclusions were reached: (a) for high-quality injection, portland-cement grouts cement:water = 1.0, 35-0, 45) should be used; (b) the mineralogical composition of cement effects grout viscosity; (c) for preventing crack formation in structures due to minus temperatures in winter, it is recommended to use injection grouts: portland-cement:water = 1.0.35-0.4 with the addition of 0.1 percent of "Mylonaft" by weight of cement.

L'INJECTION ET SES PROBLEMES (INJECTION GROUTING AND ITS PROBLEMS) P

Cambefort, H.

Bulletin Technique de la Suisse Romande, vol.87, no.19, p.329-341, September 23, 1961.
Review of knowledge on grouting; grouting for various purposes including waterproofing and consolidation; techniques of boring; types of injectors, mixture and viscosity of grout; cracks and damage caused by injection pressures.

SCHLITZWANDE FUR FRUNDUNGEN IN DER CSSR (SLURRY TRENCH WALLS FOR FOUNDATIONS IN CZECHOSLOVAKIA) P

Cernak, B.

Bauplanung und Bautechnik, vol.24, no.9, p.429-432, 1970.
Describes various types of grabbers--hydraulic, single rope, double rope--used in Czechoslovakia to supplement multi-purpose excavators. Power plant construction and the construction of waterproof blankets to prevent underflow from river dikes. The construction pit for a theatre, pumping works where there is a high water-table, chimney and bridge foundations, and underground railway construction.

QUELQUES RESULTATS DE TRAITEMENTS PAR INJECTION DE TERRAINS SANS COHESION (SOME RESULTS OF TREATMENT OF COHESIONLESS SOILS BY GROUTING) P

Chadeisson, R.R.

Genie Civil, vol.139, no.17, p.354-360, September 1, 1962; no.18, p.374-379, September 15, 1962.
Examples of dams in Algeria, Canada, Hong Kong, West Germany and France. Two dikes in France and an underground basilica in Lourdes demonstrates efficiency and performance of grouting.

DRILLING AND GROUTING AT GRAND RAPIDS P

Collett, Lee

Canadian Mining Journal, vol.86, p.43-45, March 1965.
Largest drilling and grouting job in the world at Grand Rapids, Manitoba. Main contract originally called for diamond drilling just over 1,000,000 lineal feet and to inject about 1,500,000 cubic feet of solids of which 1,000,000 cubic feet was to be portland cement and the balance clay, sand, and bentonite along with calcium chloride.

TESTS OF GROUTED ANCHOR BOLTS IN TENSION AND SHEAR P

Conard, R.F.

American Concrete Institute Journal, vol.66, no.9, p.725-728, September 1969.
A variety of fastening systems are used when anchoring to concrete. The objective of this study was to determine some of the loading characteristics of several types of grouted anchor bolts. Three types of grout and two sizes of bolts were used. The tests were divided into two parts - a pullout or tension test and a shear test.

Twenty-four test blocks were cast at the same batch of ready-mixed concrete from a local plant. The entire group of blocks was cured for 28 days prior to drilling and grouting the anchor bolts. The holes were drilled, cleaned of loose particles, and moistened with the liquid used in the grout. The bolts were placed in the hole with the grout placed after the bolts were in the hole. The bolts were agitated to consolidate the grout around the bolts, and then the excess grout was struck off flush with the top of the holes. The tests were conducted from eight to twelve days after grouting. In the tension or pullout tests, the results obtained were dependent on the bond developed at the bolt-grout interface and at the grout-concrete interface. In general, the bond failures occurred at the grout-concrete interface first, and was the major cause of failure. In the shear tests, except for the test blocks which cracked under load, the failures were a combination of crushing of the grout under the bolt, and bending of the bolt. None of the bolts failed in direct shear. The type III performed the best in both the pullout and the shear tests.

ONE OF A KIND; THE SAC GROUT TEAM C

Craig, W.E.

Air Force Civil Engineer, vol.12, no.4, p.14-16, November 1971.
The only authorized Grout Team in the Air Force is operated by the Strategic Air Command primarily trained to perform chemical grouting of structural water leaks. The team also has the equipment and experience for foundation stabilization. The grout normally used is composed of two chemical solutions that produce a very stiff gelatinous material when mixed. This grout is used to stop water leaks in structures by either structural or blanket grouting. Structural grouting provides a seal within the structural member to stop water intrusion. A hole is drilled in the structure to intercept the leak path. Chemical grout, forced under pressure into the hole, flows along the leak path back to the interior surface. The time required to form a gel after mixing the 2 solutions can be adjusted so that the chemical will set as it reaches the interior surface, thus plugging the leak path. Exterior or blanket grouting provides a seal on the exterior underground surface of the structure. This method is used when extensive leaks are found in porous concrete walls. A series of holes is drilled through the wall from the interior and a small quantity of grout is forced into each hole. The grout will usually tend to form a mass or blanket on the outside that acts as a water barrier. In addition, some grout usually flows into the leak paths with the water, thus providing an additional seal.

GROUTING PREPLACED AGGREGATE TO FORM CONCRETE P

Crosby, A.B.

American Society of Civil Engineers, Annual and National Environmental Engineering Meeting, St. Louis, Mo., October 18-22, 1971, Meeting Preprint 1523.

Clean sand-cement or soil-cement slurries have long been used for low pressure backfill grouting of rubble or rock fill where strength is not an important consideration. These long accepted practices serve as a background of prior art from which preplaced aggregate concrete evolved. In this method of placing concrete the forms are first filled with clean, properly graded coarse aggregate. Then a structural quality grout is introduced into the voids of the aggregate mass to produce structural or mass concrete. This method of placing concrete is especially adaptable to underwater construction because of the ability of the grout to effectively and cleanly displace water surrounding the aggregate. Also, it is adaptable to masonry repairs, and in general to new structures where placement by conventional means is unusually difficult, or where concrete of low volume change is required. This method of placing concrete has been used in the construction of bridge piers, atomic reactor shielding, and in reactor vessels. It has also been used to form plugs for outlet works in dams and in tunnels, for embedment of penstock and turbine scroll cases, and for a variety of repair work.

VERSATILE GRIPPER, FILLER, AND LEVELER--EPOXY GROUTING M

Delmonte, J.

Plant Engineer, vol.18, no.12, p.118-120, December 1964.

Increasing use of epoxy plastics for positioning steel bolts in concrete, leveling pads for heavy equipment, and mounting machines on concrete floors due to minimum shrinkage and good adhesion. Economical and rapid as space and void filler.

VERPRESSUNGEN MIT HEISSEM BITUMEN (GROUTING WITH HOT BITUMEN) M

Dempwolff, R.

Vortrage Baugrundtagung den Deutschen Gesellschaft fur Erd-und Grundbau, (Essen), p.209-229, 1969.

Describes the method and the equipment use for the grouting of permeable soils and structures with hot bitumen. Some examples of application given are: grouting of fault rock and voids in foundations for dams, subsealing of concrete slabs for motorways, and lifting of railway superstructures.

CHEMICAL GROUTING AT NORAD C

Erickson, H.B.

Symposium on Rock Mechanics, 6th, Rolla, Mo., October 1964, Proceedings, p.87-97.

The information presented in this paper was obtained from laboratory tests and injection of chemical grout in fractured granite at the NORAD Underground Combat Operations Center, near Colorado Springs, Colo., by the Omaha District of the U.S. Army Corps of Engineers. The purpose of the injection of chemical grout was to stabilize and strengthen areas of faulted rock where relaxation and possible transfer of stress was causing movement. Injection of the chemical grout was also necessary to provide additional strength to the rock in order to resist possible future dynamic loading. A new specially formulated stress-relieved epoxy resin grout was used for grouting of the rock. Simple equipment was devised for injection of grout holes and for injection into grout of rock bolt holes. Movement gages installed in one area indicated that movement stopped after injection of the epoxy resin; other observations also indicated the areas were benefited by grouting. This report describes the first phase of the work done in one corner of a chamber intersection in June 1963 and also a second phase of the work done in November 1963. The second phase of the work consisted of injecting additional grout in the first corner and in adjoining corner of the same chamber wall adjacent to this corner.

STRENGTHENING ROCK BY INJECTION OF CHEMICAL GROUT C

Erickson, H.B.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.94, no.SM1, p.159-173, January 1968, Paper 5744.

Brief description on planning a chemical grout operation and selecting a chemical grout. Short description of epoxy resins and polyester resins are given. Some equipment described. Epoxy resin grouting at NORAD, final laboratory tests, and conclusions from grouting are discussed.

GROUTS AND GROUTING: SURVEY OF MATERIALS AND PRACTICE P

Flatau, A.S., Brockett, R.W., and Brown, J.V.

Civil Engineering and Public Works Review, vol.68, no.804, p.591-601, July 1973.

Reviews grouting applications in ground stabilization, post-tensioning cable duct grouting, crack filling, and bed-plate and anchor grouting. Examples of current usage and data on various grouts.

FLY ASH IN GROUT P

Civil Engineering and Public Works Review, vol.57, no.676, p.1413-1417, November 1962.

Fly ash (pulverized fuel ash) is being used in lieu of sand and as a partial cement replacement in high and low pressure grouting and can be used neat in a slurried form for void filling when strength is not critical. Some fly ashes have a specific surface area as high as 5000 sq cm/gram which improves pumping conditions, keeps grout in suspension and reduces sedimentation. The lubricating action of the fly ash particles, which are spherical in shape, is of particular importance for pumping lean concrete.

MAINTENANCE AND REPAIR OF CONCRETE AND MASONRY STRUCTURES; EPOXY PRESSURE GROUTING M

Fuller, J.D., and Kriegh, J.

Tucson, University of Arizona, Final Report, July 1971.

Existing and revised methods used for pressure grouting cracked concrete and masonry were studied. Hand gun and pressure tank grout injecting equipment were studied as well as epoxy resin grouts. The best characteristics of several grouting methods were combined to develop a new technique. Grouting materials were selected on the basis of viscosity and bonding capabilities. Laboratory studies led to curves providing an estimate of flow rate of a grout within a given crack width as a function of grout viscosity.

GROUTING IN STRUCTURAL ENGINEERING AND THE APPLICATION OF EPOXY RESINS P, M

Goodall, P.D., and Husband, H.C.

Structural Engineer, vol.50, p.495-505, December 1972.

Describes typical grout applications where grout properties are of critical importance. The properties of grouts based on portland cement, polyester resins, and epoxy resins are examined and compared. Applications of epoxy resin grouting to the main bearings of the Britannia Bridge and to the expansion joints of the Weaver Viaduct are also described.

GROUT CURTAIN SEALS EXCAVATION P

Engineering News-Record, vol.181, no.27, p.67, 28 November 1968.

Oakland, California's Transbay Tube for Bay Area Rapid Transit District. Grout pumped into bedrock to form a curtain to seal off water flow. Second stage grouting reduced flow to 10 gpm.

GROUT INJECTION WORK IN CANADA AND PAKISTAN P

Civil Engineering and Public Works Review, vol.58, no.684, p.881, July 1963.

Discusses a successful wet sinking operation in Goderich, Ontario, and the use of grout curtains at a thermal power station construction site at Sakkur, Pakistan.

UNDERGROUND STRUCTURES IN LOW-COHESION, GRANULAR SOILS, INJECTION TREATMENT PRIOR TO SEALING AND STABILIZATION P

Haffen, M.

Bergbauwissenschaften, vol.17, no.8, p.290-294, 1970.

Reviews the development of the injection technique and discusses the various methods and materials. Five examples of application in practice are demonstrated. Sectional drawings show specific arrangements of the injection boreholes.

TESTING OF LARGE CURVED PRESTRESSING TENDONS P

Harstead, G.A., Kummerle, E.R., Acker, J.C., and Porat, M.M.

American Society of Civil Engineers, Journal of the Power Division, vol.97, no.PO2, p.475-492, March 1971, Paper 7966.

The basic objectives of Phase III of the Grouted Tendon Program was to demonstrate reproducibility of the satisfactory results achieved with strand tendons in Phases I and II, using, insofar as possible, the materials, equipment and procedures proposed for the structure in a test member simulating the most difficult part of the containment cylinder with respect to tendon grouting. Confirmation of the adequacy of the coefficient of friction established on the basis of industry codes, tests and experience was to be obtained through measurements of forces imposed on the tendons at the jacks using previously calibrated pressure gauges, and, at the opposite end, anchorages utilizing load cells. A measure of the bond strength developed between the tendons and the test member was to be obtained by subjecting the tendon to a series of tension tests at the jacking end. The tension test was to be repeated as the tendon was made shorter by burning it through at points progressively closer to the jacking end until the jack extended without increased force, indicating bond failure. This would measure approximate length of imbedded tendon required to develop strength capacity of the tendon through bond.

NIEKTORE PROBLEMY ZAKLADANIA STAVIEB V PIESCITYCH VODOV NASYTENYCH ZEMINACH A ICH VPLYV NA OKOLITU ZASTAVBU (SOME PROBLEMS OF FOUNDATION OF STRUCTURES IN SATURATED SANDY SOILS AND THEIR INFLUENCE ON THE NEIGHBORING STRUCTURES) P

Hartel, K.

Inzenyrske Stavby, vol.20, no.11, p.423-425, 1972.
Describes damage in the foundation work in an area where a 16.5 m thick layer of sand was underlain by marl, the groundwater level lying close to the surface. The surrounding ground settled irregularly and it was stabilized in two stages. During the first stage the resulting caverns were grouted with cement mortar. During the second, the soil was grouted with a clay-cement mixture.

EPOXY-RESIN GROUTING IN LARGE UNDERGROUND OPENINGS M

Hauge, P., and Hoffmann, W.

International Symposium on Large Permanent Underground Openings, Oslo, 1969, Proceedings, p.323-336; Oslo, Universitetsforlaget, 1970.
Moist areas of excavations for galleries below the rock surface for the storage of liquid ammonia were grouted with a suspension of cement and bentonite or a two component epoxy resin.

INSTALLATION, PRESSURIZATION, AND GROUTING OF HYDRAULIC FLAT JACKS IN MORROW POINT POWER PLANT P

Haverland, M.L.

Denver, Colo., U.S. Bureau of Reclamation, REC-OCE-70-19, June 1970.
The 5 phases covered in the Hydraulic Flat Jack Program at Morrow Point Powerplant, Colo. are: (a) calibration and testing; (b) installation; (c) instrumentation and measurements; (d) pressurization; and (e) grouting. The flat jacks were imbedded in the concrete walls on opposite sides of the underground chamber, utilizing the interior walls and floors as load-bearing struts. The jacks were intended to keep the internal concrete structures in contact with the rock excavation in the area of a large shear zone. Type V cement was used along with a small amount of aluminum powder which was pumped by a constant pressure pump at high pressure.

THE REPAIR OF CRACKED STRUCTURES BY MEANS OF RESIN INJECTIONS M

Hewlett, P.C.

Symposium on Epikote Resins in the Construction Industry, London, June 1969.

Cracked concrete structures may be repaired with synthetic resins in some circumstances. This paper presents a discussion and review of the technique, followed by a description of the injection of both neat and modified epoxy resin-based grouts into simulated cracks. In water-saturated concrete cracks, the results showed tensile strengths of the bond between grout and concrete in excess of the tensile strength of the concrete. Dry cracks in mortar gave similar results. In contrast, water saturated mortar cracks gave variable bond strengths, unless the grout contained an adhesive promoter. The following general conclusions may be drawn: (a) under suitable conditions, fine cracks in concrete or mortar can be successfully bonded by injection of any of the resin systems studied; (b) consistent and high tensile bonding in dry concrete or mortar cracks is readily achieved with any of the above formulations; (c) adhesion in wet cracks can be variable; however, wet concrete cracks may be successfully bonded without special pre-treatment or resin modification; (d) incorporation of a silane adhesion promoter in the resin can greatly enhance the reliability and successful bonding in a water-filled crack; and (e) it has not been established that flushing of a water-filled crack with methanol prior to resin injection upgrades the bonding capacity of the resin.

PRESSURE GROUTING DAMP MASONRY BY INJECTION OF LATEX-SILICONATE COMPOSITIONS — M

Hurst, H.

Rubber Developments, vol.21, no.1, p.37-43, 1968.
Latex-siliconate waterproofing compositions can be injected into holes drilled in masonry to form horizontal or vertical damp-proof courses; application of this technique to grouting of cracks in concrete construction, subway tunnels, basements, asphalt roofing, swimming pools, and ornamental ponds.

INTRODUCTION TO ALLUVIAL GROUTING — M

Surveyor, and Municipal and County Engineer, vol.121, no.3644, p.399-401, 7 April 1962.
The application of the single fluid injection process in construction is discussed. Types of grouts are discussed, as well as injection methods and control of injection. Examples of grouting treatment are given.

CREEP IN GROUTED SLEEVE SPLICES OF REINFORCING BARS — C, P

Ivey, D.L.

Civil Engineering, vol.36, no.8, p.54-55, August 1966.

A ribbed metal sleeve filled with cement grout offers a way to splice reinforcing bars. This splice utilizes the cement grout to transfer the force from one reinforcing bar into the sleeve and from the sleeve into the other reinforcing bar. In order to measure the slip of reinforcing bars in such a splice, a series of tests were carried out by the writer at Texas A&M University. The bonding material introduced in the annular space between the reinforcing bar and the sleeve was a non-shrinking premixed grout. The grout was placed in the test sleeve before the bar was introduced and the excess grout was allowed to flow over the lip of the sleeve. The sleeves were tested after seven days of curing in laboratory air. The gage arrangement allowed the slip to be measured both at the loaded end and at the free end of the reinforcing bar. Each splice tested was half of a complete sleeve splice. This arrangement was used so that the slip of the free end of the bar, at what would be the center of a complete splice, could be measured.

THEORIE UND PRAXIS EINES NEUZEITLICHEN VERANKERRUNGSVERFAHRENS (THEORY AND PRACTICE IN MODERN ANCHORING METHODS) P

Jessberger, H.L.

Bautechnik, vol.40, no.7, p.226-232, July 1963.
Construction of anchors made by pressure grouting, for erecting bulkheads, levees, retaining walls, and other structures. In German.

ETUDE D'UN COULIS DE PERFORMATION UTILISE POUR LA MISE EN OUVRE DE PAROIS PREFABRIQUEES AU CHAUTIER EXPERIMENTAL DU METRO DE LYON (STUDY OF A SELF-HARDENING GROUT FOR PLACING PREFABRICATED WALLS ON AN EXPERIMENTAL WORKING SITE FOR THE METRO SYSTEM OF LYON) P

Kastner, R., Lareal, P., and Caron, C.

Construction (Paris), vol.29, no.3, p.73-82, 1974.
Describes the characteristics of a clay-cement grout applied in-situ during the embedding of prefabricated walls at an experimental working site for the Metro System of Lyon. A systematic study is made of the grout-soil mixture used in the river alluvia which are characteristic of the Lyon site.

CHEMICAL GROUTING SUCCESSFUL IN ICBM CONSTRUCTION C

Kaufman, A., and Mahoney, G.T.

Air Force Civil Engineer, vol.3, no.4, p.18-20, November 1962.
Subsurface water was controlled by three general techniques: (a) dewatering by pumps; (b) grouting soil stabilizers into noncohesive,

unstable strata, and (c) injecting grout to form a cylindrical dike in water-bearing strata to prevent inflow of water. Pressure grouting is used, where chemical grouting fluids are forcibly injected into subsurface seams, in which the grout solidifies and inhibits the flow of water. Special grouting techniques used at different ICBM construction sites are discussed.

CONSTRUCTION DES ACCES A LA STATION "RUE DU TELEGRAPHE" DE LA LIGNE METROPOLITAINE NO. 11 DE LA PLACE DU CHATELET A LA PORTE DES LILAS — C, P

Klerlain

Genie Civil, vol.108, no.2811, p.597-603, June 27, 1936.
Construction of subway station; excavation by means of freezing; cement grouting and silicate grouting.

CEMENT AND CLAY GROUTING OF FOUNDATIONS: PRESSURE GROUTING WITH PACKERS — P

Lippold, F.H.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.84, no.SM1, 10p., February 1958, Paper 1549.
Technique of pressure grouting with packers to create water barrier; advantages and disadvantages discussed.

GROUND ANCHORS AT DEVONPORT NUCLEAR COMPLEX — P

Littlejohn, G.S., and Davies, C.T.

Ground Engineering, vol.7, no.6, p.19-24, November 1974.
The construction of the nuclear submarine complex at Davenport is discussed, including design aspects, rock/grout bond, tendon/grout bond, well anchors, tendon installation, anchor installation, and grout injection.

REPORT ON WATER SEEPAGE CONTROL IN UNDERGROUND MISSILE FACILITIES — C, P

Mahoney, G.T.

Norton Air Force Base, Calif., Engineering Division, Facilities Design Directorate, Ballistic Systems Division, Air Force Systems Command, June 1963.

A representative number of subsurface water problems occurring during missile facility activation; guidance on successful methods for correcting them. When the grouting method was used it included the (1) jello-like grouts, (2) silicate grouts, and (3) cement grouts.

GROUT-FILLED NYLON BAGS SPEED ALDERNEY BREAKWATER REPAIR P

Mardel, J.C.

Civil Engineering and Public Works Review, vol.64, no.759, p.997-999, October 1969.
Nylon bags filled with grout used to seal cavities along sea side of a breakwater. Mesh reinforcement was used to hold bags in place. A bag with a grout hose attached was placed and grout pumped into the bag. The grout used consisted of 1:1-1/2 cement/sand mix with a 0.5 water/cement ratio and a patented additive. The additive contained a plasticising, retarding, and expanding agent. The bags used had a tensile strength of 250 psi, and could take up to 18 ft head of grout on a 3-ft-diameter bag, or nearly double that head under water. The job was successful.

MEMBRANE GROUTING PROCESS USED FOR CUT-OFF P

Civil Engineering and Public Works Review, vol.58, no.687, p.1278, October 1963.
A screen grouting process is used for forming a water-tight cutoff at the Offord Intake Works. The grouting plant consists of a high-speed mixer for dealing with raw clay and mixing it with cement and a small percentage of bentonite. The mixed grout is stored in an agitator and a high-pressure, air-driven injection pump transfers it to the grout pipe and supplies the pressure to force it into the ground.

CEMENTATION OF ROCKS IN VIEW OF BUILDING UNDERGROUND AND HYDROTECHNICAL STRUCTURES P

Morozov, S.S., Goncharov, L.V., and Baranova, V.I.

Congress, International Society for Rock Mechanics, Second, Belgrade, 1970, Proceedings, vol.3, Theme 6, no.3, p.143-148.
Discusses the controlling role of the surface-active substances on the packing and water/cement ratio characteristics of cement-grout mixtures. Stresses the necessity of taking into account mineralogical composition of ground component mixtures.

GROUTING ON THE SEA-BED AT DUNGENESS "B" NUCLEAR POWER STATION IN KENT — P

Oriani, M.

Civil Engineering and Public Works Review, vol.63, no.742, p.539-540, May 1968.

Cement, fuel ash, bentonite, and plaster used for one grout, and sodium silicate with sodium aluminate used for the other. The cement grout was used for the chalk fill.

AN ANALYSIS ON THE GROUTING WORKS MADE IN THE ADMISSION SYSTEM AT XAVANTES POWER PLANT, BRAZIL.

Paes de Barros, F.

Bulletin of the International Association of Engineering Geology, no.6, p.35-47, 1972.

A description of the water admission system of the Xavantes Power Plant in Brazil is presented. The methods used for grouting, based on the analysis of experimental grouting tests, and the results of connection, consolidation, and pre-stressing grouting are described.

DEVELOPMENT, TEST, AND EVALUATION OF AN UNDERWATER GROUT-DISPENSING SYSTEM FOR USE BY DIVERS — P

Parisi, A.M., and Brackett, R.L.

Port Hueneme, Calif., Civil Engineering Laboratory, Naval Construction Battalion Center, Technical Note N-1347, July 1974.

Diver-installed seafloor fasteners are used extensively for stabilizing submarine cables and securing structures to rocky areas of the ocean bottom. Under the sponsorship of the Naval Facilities Engineering Command, Civil Engineering Laboratory extensively investigated techniques and equipment to improve the quality of the fastener systems and to reduce the amount of work required of the diver for their installation. As part of this task the Laboratory developed a diver-operated underwater grout dispenser for use with various types of groutable rock anchors. This hydraulically-powered dispenser allows the diver at the work site to have complete control of the grouting operation and improves the strength of the attachment by minimizing the amount of seawater that is mixed with the grout. This report discusses the development of an experimental diver-operated grout-dispensing system and presents results of tests conducted on land and under water with various types of groutable rock anchors.

PRESTRESSED TIES ANCHOR DOLPHINS P

Engineering News-Record, vol.170, no.17, p.52, April 25, 1963.
Prestressed cables anchored in rock below the river bottom tie down the new mooring and breasting dolphins at U.S. Gypsum's loading dock on the St. John's River in Jacksonville, Florida. The cables absorb energy and give recoverable deflections under impact loads. Four steel batter piles, driven to refusal in rock below the top of each dolphin, support the concrete dolphin cap. After installation of the piles, pipes and cap, the cap becomes a working platform for rotary drilling equipment. Each prestressing cable passes through the pipes and extends to the bottom of the rock socket. Non-shrinking cement grout anchors the lower end of the cable in the rock and pipe sleeve. Above the mud line, in the pipe, a chemical grout protects the cable from salt water corrosion, allows elongation of the upper portion of the cable under both preload stress and working stresses.

REPAIR ON AVONMOUTH LOCK CILL USING PRESSURE GROUTING P

Civil Engineering and Public Works Review, vol.67, p.792, p.691, July 1972.
Remedial work with pressure grouting techniques in 65-year-old, 26-ft-thick concrete cill. Cores indicated honeycombing and loose aggregate; close pattern. Pipes grouted in with underwater cement and extended to surface. Grout mixed in Colcrete colloidal mixer. Neat cement injected with an Evans--and the sanded mixes of a Simplex--double-acting ram pump; 80 tons cement--30 tons of sand. Work done for Port of Bristol Authority.

REPLACING CRACKED SEWAGE TANKS BY GROUTING AT BELFAST, IRELAND P

Engineering and Contracting, vol.42, p.15, October 7, 1914.
Tanks located in formation known locally as "sleetch" or made land. When dry it crumbles like fine sand; with a little moisture it swells and becomes like clay. Replaced by grouting under pressure.

AUFBEREITUNGSTECHNISCHE PROBLEME BEI DER HERSTELLUNG VON INJEKTIONSMITTELN (PROCESSING PROBLEMS OCCURRING IN PRODUCTION OF INJECTION SUBSTANCES) P

Ries, H.B.

Aufbereitungs-Technik, vol.1, no.4, p.184-188, April 1960.
Strengthening and impermeabilizing rock, dams, river banks, pits, and cavities by use of injection substances. Manufacturing procedures and processing problems of cement and clay suspensions. In German.

RIVER EMBANKMENT PROTECTION: NEW METHOD USED ON RIVER ARUN IN SUSSEX — C

<u>Civil Engineering and Public Works Review</u>, vol.66, no.775, p.198, February 1971.
A patented Swiss process based on the injection of a colloidal grout into a flexible framework of two layers of synthetic fabric is used to solve the problem of the protection of surfaces of water-retaining embankments against river erosion.

DAS ABDICHTEN AND VERFESTIGEN WASSERFUEHRENDER GEOLOGISCHER FORMATIONEN (PRESSURE GROUTING AND STABILIZATION OF WATER CONDUCTING GEOLOGICAL FORMATIONS) — C

Rumpf, K.

<u>Tiefbau</u>, vol.10, no.12, p.881-883, December 1968.
Application of pressure grouting techniques for strengthening of underground construction sites--physical and chemical characteristics. Shore stabilization developments. In German.

RECONSOLIDATION IMPROVES GROUTED MASONRY WALL PANELS — P

Sahlbert, M.W.

<u>American Concrete Institute Journal</u>, vol.32, no.6, p.689-696, December 1960.
The type of wall described is actually a reinforced concrete wall cast between bricks or masonry units which act as absorptive forms. The test described was started to demonstrate the practicability of high-lift grouting of cavity-masonry walls. Some panels were made without vibration, some used vibration or tamping, and others utilized vibration and revibration.

GROUTING TESTS ON LARGE POST-TENSIONING TENDONS FOR SECONDARY NUCLEAR CONTAINMENT STRUCTURES — P

Schupack, M.

<u>Prestressed Concrete Institute Journal</u>, vol.16, no.2, p.85-97, March-April 1971.
Tests of sedimentation (bleeding) and expansion of neat cement grouts were made as part of a program to insure successful grouting of large-capacity, long, vertical, post-tensioning tendons, and large-capacity tendons on sharp curvatures. Water-reducing and expansion-producing admixtures for grout are recommended, together with standpipes at all high points of the tendon, to assure elimination of voids.

SMALL HOLES ANCHOR BIG PILES P

Engineering News-Record, vol.178, no.9, p.38-42, March 2, 1967.
Anchoring hollow precast concrete piles saved City of New York more than $750,000 on the Rikers Island Bridge. Dry grout wrapped in a plastic "sausage skin" was preplaced. Tapping bars into place ruptured the plastic permitting hydration to begin and packing the material tightly around bar.

FLY ASH IN GROUT

Smith, P.H.

Civil Engineering and Public Works Review, vol.57, no.676, p.1413-1417; vol.57, no.677, p.1558-1560, December 1962.
Topics discussed strength and sulphate resistance of fly ash/cement grout, lightweight grouts, miscellaneous applications, mud jacking, fire control on tips, oil well grouting, grouting pre-placed aggregate, and mixed-in-place piles.

PAROIS SOUPLES MOULEES DANS LE SOL AVEC UN COULIS DE PERFORATION BENTONITE-CIMENT (FLEXIBLE DIAPHRAGM WALLS CAST IN SITU WITH A BENTONITE-CEMENT DRILLING MUD) M

Tornaghi, R.

European Conference, Soil Mechanics and Foundation Engineering, 5th, Madrid, April 1972, Proceedings, vol.1, Theme 4, p.577-583.
Development of new method for the construction of flexible-diaphragm walls cast in situ. Mortar used to support walls of the excavation and is also the definitive fill of the ditch. Advantages over earlier methods are increased deformability, simpler installation and lower costs. Use of static analysis illustrates influence of the most important factors. In French.

PRESSURE GROUTING: AN IMPROVED METHOD OF OFFSHORE STRUCTURE GROUTING

Tragesser, A.F., Dalton, Charles, and Kay, F.J.

Sixth Annual Offshore Technology Conference, Houston, Texas, May 6-8, 1974, Preprints, vol.2, p.505-512.
A new method of grouting the legs of offshore oil platforms has been evaluated with respect to resultant grout quality, economics, and reliability. The results from the scale model tests and from field operations show that a high quality grout column can be obtained by the new method and that the process is feasible from an economic and operational standpoint.

THE TREATMENT OF UNSTABLE SLOPES, GROUTING, REINFORCEMENT AND DRAINING, AND THE IMPORTANCE OF DEFINING THE SLIP PLANE P

Railway Gazette, vol.120, no.14, p.610-612, July 17, 1964.
The system of determining the position of the surface plane of the slip by the use of the polythene tube method. The system is referred to in this article in the description of a method of stabilizing embankment slips by cement grouting. A system of cement grouting for stabilizing slips in embankments and cuttings has been developed in the Western Region of British Railways over the past 10-15 years. The method originated in America and after its successful development in Britain has been introduced to the French National Railways. It is applicable to practically all embankment slopes and to some cuttings.

UNDERWATER GROUTING AT AVONMOUTH P

Concrete, vol.6, no.5, p.31, May 1972.
Discusses pressure grouting techniques at Avonmouth Docks. The injection sequence for each hole was (a) neat cement grout was pumped through a plastic tube until good grout overflowed the standpipe; (b) the plastic tube was removed and a flexible pressure hose was connected to the standpipe; (c) pumping commenced slowly and was continued until the predetermined pressure limit was reached. Divers checked for interconnection with other holes, and when good grout flowed from any standpipe, the hole was isolated by closing the inlet valve on the standpipe.

FOUNDATION GROUTING OPERATIONS, SAVANNAH RIVER PLANT P

U.S. Army Engineer District, Charleston

Vicksburg, Miss., Waterways Experiment Station, 1952. Conducted for the Atomic Energy Commission and E.I. Du Pont de Nemours & Company.
Geologic and engineering foundation investigations for the Savannah River Plant structures revealed that foundation conditions were, in some respects, unusual, and that grouting would be required beneath some of the principal structures. A rapid type of wash boring was utilized, referred to as "fishtail" borings, which demonstrated whether or not grouting would be required by the manner in which the boring and equipment behaved during drilling. If circulation of drilling water or mud could not be maintained during drilling, or if the drill rods dropped or settled abnormally, the boring was grouted by means of large grout mixers and pumps. Unconfined compression tests on samples of the grout indicated a compressive strength of from 4 to 5 tons per sq ft after 28 days. This strength is considered more than ample for the purpose. Grouting of the foundation beneath selected structures is considered to have practically removed the danger of any sudden movements due to subsidences resulting from

previous solution of material in the foundation. It must be admitted, however, that because of the solution processes it cannot be assumed that the danger of any movement is completely eliminated. It is not anticipated that the grouting accomplished will influence normal settlement of structures due to consolidation of the foundation soils.

INTAKE STRUCTURES AND PENSTOCK LINERS; FOUNDATION AND GROUTING REPORT, CARTERS DAM, CARTERS, GA. M

U.S. Army Engineer District, Mobile

Mobile, Ala., no date.
Discusses subsurface exploration, geology, excavation, foundation preparation, curtain grouting, in esplanade area, and penstock tunnel lining and grouting. One of the recommendations was that holes for gravity grouting should have a diameter 3 times the diameter of the grout pipe to eliminate grout from forming a packer-like block in the annular space between the rock and pipe. Also, a pressure gage should be installed between the pump and the hole as an increase in pressure will indicate a grout block.

BOND OF PORTLAND-CEMENT GROUT TO LARGE-DIAMETER STEEL CASING P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-862, December 1966.
A study was performed by R.A. Bendinelli and B.R. Sullivan to proportion a grout mixture which would support an 18-inch-diameter line-of-sight pipe and 48-inch casing. These were grouted with various grout mixtures and subjected to load at 24- and 48-hr ages in a 1,500,000-lb-capacity testing machine. Grout-casing bond strength and curing temperatures which met the required design criteria were obtained.

CONSTRUCTION AND PERFORMANCE OF THE GROUTED CUT-OFF, ROCKY REACH HYDROELECTRIC PROJECT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.2-417, March 1961.
Since experience in the construction of grout curtains is limited and the detailed records of such work are almost nonexistent, the purposes of this investigation are to: (a) describe the engineering problems encountered and the construction methods used to provide an adequate grout curtain under the conditions present at Rocky Reach; (b) determine from the available data the effects of soil type and grain size, grout type, viscosity and grain size, hole spacing and pattern, construction sequence, injection pressure, and pump charac-

teristics upon the quantity of grout injected and the distribution of that grout within the soil deposit; (c) determine from a study of the available data whether the grouting specifications and criteria were adequate to produce an effective cutoff economically; (d) evaluate the actual and anticipated performance of the grout curtain by analysis of the construction methods, the permeability test records, and the piezometric observations. This paper was prepared by J.E. Wagner.

INVESTIGATION OF RESISTANCE OF PREPLACED-AGGREGATE CONCRETE TO FREEZING AND THAWING — P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper C-68-6, September 1968.
The objectives of this investigation were: (1) to establish whether variations in manufacturing procedures may be expected to include some which affect the frost resistance of preplaced-aggregate concrete, (2) to identify such procedures if they exist to determine if the hardened concrete can be rendered more resistant to freezing and thawing by the addition of an air-entraining admixture (AEA) to the grout mixture, and (3) to make appropriate recommendations for means by which any adverse effects encountered may be avoided in practice. This report was prepared by W.O. Tynes and J.E. McDonald.

INVESTIGATION OF GROUTS ON A COLLOIDAL CEMENT GLUE BASE FOR MONOLITHIZING ELEMENTS OF HYDRAULIC STRUCTURES — P

Ur'ev, N.B., Klimanova, A.F., and Mikhailov, N.V.

Hydrotechnical Construction, no.1, p.21-25, January 1967. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.1, p.16-18, January 1967.)
The use of injection grouts for monolithizing is discussed. The monolithizing method is explained in detail in its use in prefabricated elements of hydraulic structures.

BITUMEN IN HYDRAULIC ENGINEERING — M

Van Asbeck, W.F.

London, Shell Petroleum Co., Ltd., 1955, 2 vols.
Gives account of properties of bitumen, including its qualities for injection work. Includes brief accounts of recent works in hydraulic engineering using grouting.

VIBRATED MEMBRANE EXCLUDES GROUND WATER; DRY EXCAVATION FOR DATCHET INTAKE WORKS P

Contract Journal, vol.232, p.292-294, 20 November 1969.
Describes method of grouting used during construction of a siphon and intake channel from the River Thames.

ROCK EXCAVATION AND CONSOLIDATION OF UNDERGROUND POWER STATION IN SCOTTISH HIGHLANDS P

Vlatseas, S.

Water and Water Engineering, vol.69, no.830, p.146-149, April 1965.
Excavation and tunneling work in construction of low pressure tunnel is described. Rock had to be extensively rockbolted and cement grouted and walls lined with concrete.

SITE CONTROL OF GROUTING MORTAR MIX P

Voves, B.

Stavebnicky Casopis, vol.18, no.3, p.218-237, 1970.
Methods of control of grouting mortar mix for the grouting of ducts in posttensioned prestressed concrete structures developed to correspond to the possibilities of construction practice. Also gives results of the tests carried out to verify the proposed methods.

DIE STABILISIERUNG VON DAMMRUTSCHUNGEN DURCH ZEMENTMOERTELINJEKTIONEN (STABILIZATION OF EMBANKMENT SLIDE BY CONCRETE MORTAR INJECTION) M

Wagner, O.

Tiefbau, vol.6, no.10, p.805-810, October 1964.
Methods applied on British and French railroads are outlined and experiences of German practice discussed. In German.

WHAT YOU SHOULD KNOW ABOUT THE "MUD-JACK" SLAB LEVELING METHOD P

Engineer and Contract Records, p.52-53, January 1973.
The method consists of pumping a cement-containing sand-soil grout to fill voids beneath settling sidewalks and slabs, dipping pavement and bridge approaches, and sunken foundations. Adding mix under pressure raises slab levels to original or correct grade, penetrates and firms the subsoil, and provides uniform support and stabilization to the structure.

GROUTED-STONE FILLED CAISSONS P

White, R.E.

Construction Methods and Equipment, vol.40, p.73-74, 76, December 1958.

Aggregate (1-1/2-inch-size minimum) used in caissons; rich grout injected through it; Colcrete Method used to obtain secure grout.

NEW METHOD OF ROCK SEALING WITH CEMENT-BASE PASTES P

Wittke, W.

VDI Zeitschrift, vol.3, no.22, p.1568-1575, 1969.

New method for sealing or stabilizing rock in the subsoil of dams, tunnels, galleries, and shafts, consists of injecting a cement paste with admixtures of clay and water from the borehole into the fissures. Reduction of number of boreholes needed and a saving in working time and injection material.

VIII. - ROCK-BOLT GROUTING

VERPREBANKER ZUR SICHERUNG TIEFER BAUGRUBEN (GROUTED ANCHORS FOR SECURING DEEP TRENCHES)

Boenke, R.

Eisenbahntechnische, vol.25, no.11, p.389-391, 1974.
The creation of open trenches is briefly described. Back-anchoring with the aid of grouted anchors is described in detail. A description is given of the manufacture of the grouting. In German.

UPLIFT CAPACITY OF GROUTED ROCK ANCHORS

Brown, D.G.

Ontario Hydro Research Quarterly, vol.22, no.4, p.18-24, 1970.
Forty-eight rock anchors were pulled in order to determine how depth of embedment, bar diameter, steel strength, and anchor-rod surface features affected the uplift-load capacity of rock anchors and their mode of failure. The results indicate that the capacity of anchors varies directly with the total surface area of the anchor imbedded in the grout for both deformed and plain anchors.

STRESS DISTRIBUTION ALONG A RESIN GROUTED ROCK ANCHOR M

Farmer, I.W.

International Journal of Rock Mechanics and Mining Science, vol.12, no.11, p.347-351, 1975.
Theoretical shear-stress distribution along a loaded resin grouted rock anchor is compared with computed shear-stress distribution obtained from tests on instrumented anchors in concrete, limestone, and chalk.

EIN BEITRAG ZUR ABSCHATZUNG DER TRAGFAHIGKEIT VON VERPREBAUKERN IN NICHTINJIZIERBAREN NICHTBINDIGEN BODEN (CONTRIBUTION TO THE ESTIMATION OF THE BEARING STRENGTH OF GROUTED ANCHORS IN NON-INJECTABLE, NON-COHESIVE SOIL)

Grade, H.

Mitteilungen der Instituts fur Bodenmechanik, Technische Universitat, Hannover, Germany, no.8, 1974, 138p.
There is no method of calculating the bearing strength of grouted anchors for the sides of excavations. For noninjectable, noncohesive

soil, the author studies the influence of the method of fabrication on the bearing strength of an anchor and develops a method for its proper estimation. In German.

ACCEPTABLE WATER FLOWS FOR ROCK ANCHOR GROUTING P

Littlejohn, G.S.

Ground Engineering, vol.8, no.2, p.46-48, March 1975.
Discusses flow rates, water loss, and leakage and gives recommendations for waterproofing.

ANCHORED DIAPHRAGM WALLS IN SAND; ANCHOR DESIGN P

Littlejohn, G.S., and Sliwinski, Z.

Ground Engineering, vol.5, no.1, p.12-17, January 1972.
Discusses anchor grout construction, including stability, safety factors, post tensioning, and corrosion protection. Anchor hole formation is aided by various flushing techniques. The cable, which consists of high tensile strands, wires, or bar is homed. Grout, consisting of neat cement and water is injected into the hole under pressure as the casing is withdrawn over the fixed anchor length.

ANCHORS 2; GROUND ANCHORS TODAY

Littlejohn, G.S.

Ground Engineering, vol.6, no.6. p.20-22, November 1973.
Discusses grouted anchors including permanent and temporary anchorages, test anchors, model tests, long term behavior, and corrosion protection.

ROCK ANCHORS - STATE OF THE ART, PART 2: DESIGN P

Littlejohn, G.S., and Bruce, D.A.

Ground Engineering, vol.8, no.4, p.41-47, July 1975.
Discusses grouting of rock anchors. Includes tables on grout/wire bond values, and grout/strand bond values.

SEALING OF RECHARGE WELLPOINT SYSTEM WITH AM-9 C

Magielnicki, J.S., and Drake, J.K.

Wayne, N.J., American Cyanamid Co., June 1964.

The objective was to maintain the existing water level in the area adjacent to excavation for new construction. A bentonite grout failed; AM-9 was successful.

MOORING IN BASALTIC ROCK M

Seattle, Wash., Oceanographic Institute of Washington, Program Plan, July 1970.

The operations are planned to include drilling three core holes in the pinnacle to obtain sample cores; grouting in rock bolts in the core holes to serve as moors, and testing one rock bolt to failure.

YIELDABLE ROCK BOLTS FOR SHOCK LOADING AND GROUTED BOLTS FOR ROCK STABILIZATION P

Ortlepp, W.D., and Reed, J.J.

Mining Engineering, vol.6, no.3, p.12-17, 1970.

Theoretical analysis and on-site test results, which used a recently developed yielding device, is presented on the stabilizing effects of placing fully-grouted rock bolts immediately after excavation. The strength of the fractured rock tends to promote stability provided it is retained in position.

POLYESTER RESINS USED IN CYANAMID'S METHOD FOR ROCK WALL STABILIZATION P, M

Mining and Chemical Engineering Review, vol.56, p.10-11, December 1964.

Rock walls stabilized by using wire mesh and Roc-Loc grouted rock bolts or reinforcing bars; Roc-Loc resin has higher tensile strength than concrete.

ROCK BOLTS ALONE SUPPORT HUGE CAVERN ROOF P

Engineering News-Record, vol.178, no.1, p.22-25, August 4, 1958.

British Columbia's Portage Mountain Dam. Excavation of arch roof for underground powerhouse.

REPORT OF ROCKBOLT FIELD TESTS; CLARENCE CANNON PROJECT, MISSOURI C

U.S. Army Engineer District, St. Louis

St. Louis, Mo., September 1974.

Extensive use is being made of rockbolts and anchors at the Clarence

Cannon Project in both limestone and weak shale formations. Difficulty was experienced in obtaining sufficient anchorage for required prestressing during preconstruction rockbolt testing in the Hannibal shale formation. The problems in that test program were evaluated as resulting from installation and drilling techniques in the case of grouted anchors and from insufficient strength of the shale in the case of grouted anchors and from insufficient strength of the shale in the case of mechanical anchors. A few four-foot anchors were later installed encapsulated in polyester resin. This type of anchorage seemed to be promising; however, due to the insufficient amount of testing, rockbolt performance was specified rather than an end product. The contractor elected to use "Dywidag" thread bars anchored and grouted with polyester resins. The system formed by the combined use of these two products exceeded design requirements by a wide margin. The test program provided a large amount of useful data which revealed the system to be simple, economical, versatile, and effective. This report was prepared by J.A. Albritton.

IX. - GENERAL RESEARCH

DEVELOPMENT AND APPLICATION OF TIEBACKS AND SOIL ANCHORS IN OPEN FOUNDATIONS

Acker, W.L.

Annual Engineering Geology Soils Engineering Symposium, Idaho Department of Highways, 6th, Proceedings, April 1972, p.257-262.
The use of tiebacks in soil and rock is becoming more accepted in construction. Anchors in rock seem to enjoy wider acceptance than the earth tieback. The strength of these tendons is basically due to the bond between the rock and the grout.

METHODS OF IMPROVEMENT OF THE PROPERTIES OF FISSURED ROCK MASSES BY INJECTING SYNTHETIC FURAN RESINS C, M

Adamovich, A.N., and Baushev, V.K.

International Society on Rock Mechanics, 2nd Congress, Belgrade, 1970, Proceedings, vol.3, Theme 6, no.2, p.137-141.
A new grout has been developed based on furan compound, Furfural, which is especially suitable for grouting thinly fissured rock. The low viscosity of furfural based resins allows grouting at low pressures. Field tests show that grouting of clay covered limestone surfaces is possible.

ADDED FLOOR STRENGTH FROM EPOXY RESINS

Contract Journal, p.316, November 16, 1967.

ADMIXTURES FOR CONCRETE P

American Concrete Institute Journal, vol.26, no.2, p.113-148, October 1954.
Admixture divided into 11 groups: accelerators, retarders, air-entraining agents, gas-forming agents, cementitious materials, pozzolans, alkali-aggregate expansion inhibitors, dampproofing and permeability reducing agents, and miscellaneous; effects expected from each group.

FREEZING BEHAVIOR OF GROUTS CONTAINING GRANULATED SLAG M

Aitcin, P.C.

American Concrete Institute Journal, vol.67, no.5, p.413-417, May 1970.

Grouts containing granulated blast-furnace slag of mellitic type after a succession of freezing and thawing cycles become coated with a thin film of resistant, finely crystallized calcite resulting from the presence of granulated slag in the grout. Tensile and compressive strengths at rupture of these grouts is notably increased by this film layer.

DETENTION AND PREVENTION OF FOUNDATION UPLIFT FROM PRESSURE GROUTING P

Akers, R.J.

Sacramento, Calif., California Department of Water Resources, Technical Memorandum no.30, March 1968.

Discusses three methods of detecting foundation uplift from excess grouting pressures: (1) precise leveling surveys, (2) the use of tiltmeters, (3) the use of extensometers or displacement gages.

HIGH TEMPERATURE EFFECTS ON THE STRUCTURAL PROPERTIES OF HAEMATITE SAND GROUT

Akolkar, P.M.

Indian Concrete Journal, vol.50, no.1, p.7-9, 31, January 1976.

Discusses the findings of some experimental work carried out on haemati.. sand grout. The annealing operation is described.

METHODS OF EVALUATION OF CONDITIONS AND EFFECT OF THE CONSOLIDATION GROUTING (O METODAKH OTSENKI USLOVII I EFFEKTA UKREPITEL'NOI TSEMENTATSII)

Allas, E.E., and Savinskaya, M.K.

Hydrotechnical Construction, no.11, November 1972. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.11, p.22-25, November 1972.)

AM-9 CHEMICAL GROUT FIELD MANUAL C

Princeton, N.J., American Cyanamid Co., Engineering Chemicals Research Center, March 1976. 4th edition.

Contains chemical data, physical data, and field equipment for AM-9 chemical grout. Also contains field procedures, factors affecting grout placement, and grouting specifications.

EPOXIES WITH CONCRETE M

American Concrete Institute

Detroit, Mich., ACI Publication SP-21, 1968.
The general aspects of the use of epoxy compounds and of epoxy curing agents for patching and grouting concrete are discussed. The successful use of epoxy materials requires that certain material criteria are met and that proper surface-preparation procedures are followed. Basic information on both these subjects is presented. This paper describes the application of epoxies for the repair of freeze-thaw damage, chert pop-out failures, damage to precast pieces and floor deterioration affected by steel-wheel vehicles. Also discussed are prevention of dusting, cavitation, cold joints, and chemical attack.

STANDARD SPECIFICATION FOR PORTLAND CEMENT P

American Society for Testing and Materials

Philadelphia, Pa., Annual Book of ASTM Standards, Part 13, p.131-137, Designation: C 150-74, 1974.
Topics covered are scope, definitions, basis of purchase, additions, chemical requirements, physical requirements, methods of test, inspection, testing time requirements, rejection, manufacturer's statement, packaging and marking, storage and manufacturer's certification. Tables cover standard chemical requirements, optional chemical requirements, and standard and optional physical requirements.

STUDY OF SUBAQUEOUS CONCRETE P

Anderson, A.R.

Journal of the American Concrete Institute, vol.8, (Proceedings, vol.33), p.339, January 1937.

PRESSURE GROUTING TECHNIQUE RAISES SUNKEN SLABS P

Anderson, Floyd

Public Works, vol.95, p.97-98, June 1964.
Discusses problem of settlement of concrete slabs and paved areas in the Tulsa, Oklahoma area. A new technique has been developed to fill the cavities and to raise the settled pavement back to its original position.

CAMANCHE DYKE-2 SLURRY TRENCH SEEPAGE CUTOFF

Anton, W.F., and Dayton, D.J.

American Society of Civil Engineers Specialty Conference, Performance of Earth and Earth-Supported Structures, Purdue University, Lafayette, Ind., June 1972, vol.1, Part I, p.735-749.
The installation of a seepage barrier by the slurry trench method effectively reduced seepage occurring in the pervious foundation materials at Camanche Dyke-2, California.

EIGENSCHAFTEN VON ZEMENTSUSPENSIONEN ZUM EALZ (QUALITIES OF CEMENT SUSPENSIONS FOR GROUTING) P

Auspressen, K.

Beton-und Stahlbetonbau, vol.49, no.9, p.205-211, September 1954.
Composition, production and properties of cement suspensions; flow capacity; influence of water cement ratio; application to concrete prestressing ducts.

GROUTING AND THE CIVIL ENGINEER M

Ayres, D.J.

Journal of the Society of Engineers, vol.50, no.3, p.107-130, July-September 1959.
Grouting is presented as a tool which the civil engineer should use as part of his normal construction methods to give the most efficient and economical job, and to overcome the view that it is some expensive specialist process to which one only turns in an emergency. A grouting process is one in which there is an intrusion in which a space is filled, or in which a space is created and filled; the material intruding is initially in a liquid form and the application is made by an applied pressure to the liquid grout. A cementitious slurry is often referred to as a grout but any liquid or emulsion or suspension may be used as a grout and it is the purpose of its use which defines it. Apart from water, grouts may be considered in four groups: soil grouts, bituminous grouts, chemical grouts, and cementitious grouts. Some examples of the different uses of grouting which are discussed include void filling for load transfer, mechanical pointing, void filling for impermeability, load transferring systems--underpinning, mud jacking, arch strengthening--settlement and bearing capacity problems, slope stability, and track grouting.

CHEMICAL GROUTING IN PERVIOUS AND ROCK FOUNDATIONS C

Badappanavar, M.G.

Journal of the Institution of Engineers (India), Civil Engineering Division, vol.54, no.C13, p.110-115, 1974.
This paper concerns the practice of chemical grouting in pervious and rock foundations. Chemical grouting involves the collection of geological information of site, selection of proper grouts, grouting equipment and grouting pattern.

GROUT/SOIL INTERACTION AND VELOCITY GAGE EMPLACEMENT FOR GROUND-SHOCK MEASUREMENT; FINAL REPORT FOR PERIOD SEPTEMBER 1975 - JULY 1976.

Balachandra, M.B., and Malthan, J.A.

El Segundo, Calif., Agbabian Associates, DNA 4089F, August 1976. Prepared for Defense Nuclear Agency.
The investigations covered a wide range of borehole/free-field impedances under a variety of interface conditions. Velocity gage canisters are recommended to be locked to the free field with a stiff, expansive grout locally around the canister in the borehole. The remaining regions of the borehole may be filled with grouts that only crudely approximate the free-field material properties.

NEYVELI FLY-ASH AS ADMIXTURE IN CEMENT GROUT P

Balasubramaniam, K.V., and Somanathan, C.

Indian National Society Soil Mechanics and Foundation Engineering Journal, vol.7, no.3, p.345-364, July 1968.
Suitability and influence on grout properties such as fluidity, jellifying time and stability experimentally determined for Neyveli fly ash as an admixture in cement grouts. Outlines different types of grout materials, requirements, functional aspects, and various methods of grouting.

EINIGE GRUNDLEGENDE FRAGEN DES SCHACHTBAUS IN NICHT STANDFESTEN DECKGEBIRGE P

Bals, R.

Glueckauf, vol.81-84, no.5-6, p.69-82, 1948.
Methods of overcoming pressure by freezing, cement grouting and electrical solidification.

THE UTILIZATION OF PULVERIZED-FUEL ASH C, P

Barber, E.G.

Journal of the Institute of Fuel, vol.43, no.348, p.4-9, January 1970.
Discusses potential uses of fuel ash as a concrete mix including use as a grouting material.

SILICA GROUTS (LES COULIS DE SILICE) C

Baron, J.

Hanover, N.H., U.S. Army Cold Regions Research and Engineering Laboratory, Draft Translation no. CRREL-TL-552, October 1976. (Draft translation of Association Technique de la Siderurgie Francaise, Commission des Cokeries (France), vol.31, no.12, p.2579-2601, 1974.)
Until recent years, the grouts used for cementing silica bricks had a quite different chemical composition and a mineralogical composition quite close to those of silica bricks. The ternary SIO_2-Al_2O_3-CAO diagram shows that these types of grouts have limiting temperatures of utilization incompatible with temperatures reached in modern coke furnaces. The grouts are therefore developed in the direction of purity and fineness in order for the ceramic setting to be reached at high temperature by sintering. The following tests were carried out on about 20 silica grouts: mineralogical and particle-size analyses, pyroscopic strength, and thermal expansion. The results of these tests have allowed specifying the limiting values of these different characteristics.

OXYGEN CONSUMPTION AND HYDROGEN PRODUCTION BY SHRINK-RESISTANT GROUTS IN CONFINED PLACES M

Barrett, M.A.

Washington, D.C., U.S. Bureau of Mines, Report of Investigations no.7267, June 1969.
Bureau of Mines conducted a laboratory scale investigation of grout-

ing mixtures containing iron or aluminum to determine the existence of health of explosion hazards due respectively to oxgen depletion or hydrogen emission. Mixtures containing iron created an oxygen deficiency in less than 24 hours and released small amounts of hydrogen; mixtures containing aluminum released little hydrogen and consumed little oxygen.

CEMENT GROUTS AND THEIR INFLUENCE ON THE SHEAR STRENGTH OF FISSURED ROCK MASSES P

Barroso, M.

International Society on Rock Mechanics, 2d, Belgrade, 1970, Proceedings, vol.3, Theme 6, no.9, p.189-195. (Also appears in Portuguese in Laboratorio Nacional de Engenharia Civil (Lisbon), Memoria no.408, 1972, and in Tecnica no.413, 1971.)

The compressive strength and water-cement ratio of grout can be evaluated by determining the apparent porosity in the laboratory. Hydraulic fracturing, expulsion of excess water, internal stressing and opening of joints are positive consequences of grouting-pressure. Excessive grout and the destruction of the rock structure are the disadvantages.

ERWEITERUNG DES BEREICHES DER ZEMENTIERUNGSARBEITEN AUF GRUND VON NEUEN EIGENSCHAFTEN DER ZEMENTSUSPENSIONEN (INCREASING THE RANGE OF GROUTING ON THE BASIS OF NEW PROPERTIES OF CEMENT SUSPENSIONS) P

Bastian, S., and Gruener, D.

Bergbauwissenschaften. vol.17, no.8, p.303-310, 1970.

Discusses the use of dilute cement suspensions in grouting works and the possibilities of improving such suspensions. A new grouting material in which part of the cement is substituted by injectol-powder is described in detail. In German.

GROUTING C, P, M

Bator, G.T., and Snow, D.T.

Annotated Bibliography of Selected Mining Subjects, Quarterly of the Colorado School of Mines, vol.61, no.2, p.128-139, April 1966.

A bibliography covering portland cement, chemical, and miscellaneous grout materials.

METHODS OF TREATMENT OF UNSTABLE GROUND

Bell, F.G., ed.

London, Newnes-Butterworths, 1975, 215p.
Contains thirteen articles dealing with modern techniques of treatment of unstable ground, including penetration of grouts, classification of grout, clay grouting and alluvial grouting.

SULFITABLAUGE ALS BASIS ZUR BETONVERFLUESSIGER (SULFITE SOLUTION AS BASE MATERIAL FOR CONCRETE GROUT) P

Benz, Gerhard

Beton-Stahlbetonbau, vol.67, no.12, p.279-382, December 1972.

EXPERIMENTATION D'UN NOUVEAU PROCEDE DE REINJECTION DES GAINES DE CABLES DE PRECONTRAINTE (NEW PROCESS FOR REINJECTING THE PRESTRESSED CABLE SHEATHS)

Berissi, R.

Laboratoire Central des Ponts et Chaussees, Bulletin de Liaison des Laboratories des Ponts et Chaussees, no.82, p.41-46, March-April 1976.
The liability of reinforcements to stress corrosion requires that prestressing steel should be efficiently protected. The grouting also insures the mechanical link between the reinforcements and the concrete of the structure.

GROUTING REPAIR OF OLD RIVER LOW-SILL CONTROL STRUCTURE

Bea, J.A.

Vicksburg, Miss., U.S. Army Engineer Waterways Experiment Station, Miscellaneous Paper no.0-74-8, "Engineering and Scientific Research at WES," p.1-2, November 1974.
Following the evaluation of approximately 30 grout mixtures by the WES Concrete Laboratory, several mixtures were recommended and subsequently used in the grouting of the structure. Grouting was accomplished from the bridge deck level of the structure for all holes. Drilling the grout holes was done not only from the bridge deck, but also from barges positioned on both the up-river and down-river sides of the structure.

AN INVESTIGATION INTO GROUT MIXES AND THE USE OF RADIOISOTOPES TO DETERMINE THE EFFICIENCY OF GROUTING — P

Boardman, V.R.

International Congress on Prestressed Concrete, 3rd, Berlin, <u>Proceedings</u>, vol.1, Paper no.1, Session no.2, p.291-303.
The author reviews the properties required of grouts for use in prestressed concrete structures, the current methods of testing and the effect of the length of mixing period on the efficiency as part of the structure. Corrugated or indented sides for prestressing ducts are advocated to enhance the bond. The efficiency of various methods of grouting are being investigated with the aid of radioisotopes.

BEHAVIOUR OF A SINGLE-LINE GROUT CURTAIN

Bolognesi, A.J.L., Moretto, O., Pronsato, D.A., and Zarazaga, C.H.

International Conference on Soil Mechanics and Foundation Engineering, Montreal, 1965, <u>Proceedings</u>, vol.2, p.456-458.
A single line of grout holes was used to construct a grout curtain below a large earth dam. The foundation was gneiss. Comparison of the observed piezometer readings at the base of the dam with the theoretical values assuming ineffective and perfectly effective curtain shows that the single curtain was almost entirely ineffective in reducing uplift pressures on the dam.

UEBER DEN EINFLUSS DES ZEMENTS UND DER EIGENSCAFTEN DER ZEMENTSUSPENSIONEN AUF DIE INJIZIERBARKEIT IN LOCKERGESTEINSBODEN (THE INFLUENCE OF THE CEMENT AND THE PROPERTIES OF CEMENT SUSPENSIONS ON THE INJECTION CAPACITY INTO SOILS) — P

Bonzel, J., and Dahms, J.

<u>Beton Herstellung Verwend</u>, vol.22, no.4, p.156-166, April 1972.
Comprehensive research work regarding the influence of cement and properties of cement suspensions on the injection capacity into loose earth, soil, and rocks. Nineteen cement suspensions differing in type, composition, fineness, and strength were examined with regard to their flow, sedimentation, and injection behavior. In German.

GROUTING IN ENGINEERING PRACTICE — M

Bowen, Robert

New York, John Wiley & Sons, 1975.
This book provides a general survey of grouting for civil engineers

and engineering geologists. All aspects of grouting are covered including the use of portland cement, clay, and chemical grouts. Compaction grouting is discussed, as well as the applications of grouting to dams. Applications of grouting to vibrating machinery foundations, deep mines, tunnels, and bridges are also discussed.

USES OF BENTONITE IN CIVIL ENGINEERING M

Boyes, R.G.H.

Institution of Civil Engineers, Proceedings, vol.52, Part I, Design Construction, p.25-37, May 1972.
Under grouting, neat bentonite suspensions are compared with bentonite suspensions to which chemical additions or fillers or setting agents such as cement have been added. Examples of grouting to seal leaks, stop water permeation, surround pipelines, cable ducts, and tunnel rings are given.

WATER IMPEDANCE WITH VULCLAY BENTONITE M

Brelaz, G.J.

Commonwealth Engineer (Australia), vol.26, no.6, p.221, January 2, 1939.
American experience in use of colloidal vulclay bentonite for waterproofing pervious sand, gravel, and masonry structures.

GROUTING PILES IN SOFT SOIL P

Brown, P.

International Conference on Soil Mechanics and Foundation Engineering, 3rd, Zurich, 1953, Proceedings, vol.2, p.10-15.
Experimental investigations of a method to mix portland-cement grout in place with soft soils to form a stabilized mass were conducted at the U.S. Naval Civil Engineering Research and Evaluation Laboratory, Port Hueneme, California, to study this method in both laboratory and field phases and to determine its applicability to water-front foundation problems. The process consists primarily of pumping grout into the soil while the soil is being mixed in place. Factors investigated include mixing equipment, grout composition, mixing procedure, strength of resulting stabilized elements, and their action as piles under vertical load. Test results indicate that the method is feasible within limits and is more adaptable for repair jobs and small-scale construction than to large-scale permanent works.

THE USE OF CEMENT GROUT AT THE DELTA BARRAGE IN EGYPT

Brown, R.H.

Institute of Civil Engineers, Minutes of Proceedings, vol.158, p.1, 1904.

BETONTECHNOLOGISCHE BETRACHTUNGEN ZUM COLCRETE-VERFAHREN P

Brux, G.

Zement-Kalk-Gips, vol.14, no.5, May 1961, p.189-201.
The fundamentals of the Colcrete Process and the characteristic features of its application are explained. Test results are dealt with, and inferences are drawn from them. In particular, the requirements applicable to Colgrout are discussed, as also the proportion of fine particles, the water/cement ratio, and grout for injection into prestressing ducts. The properties of the coarse aggregate particles for grouted concrete members loaded in bending are investigated and comparisons are made as to shrinkage behaviour. Besides dealing with the manufacture and the taking of test specimens of grouted concrete, the author discusses impervious underwater grouted concrete and gives an analysis of the economy of this method with the aid of diagrams and cost comparisons.

VERSUCHE MIT SONDERMISCHERN FUER INJEKTIONSGUT AUS WASSER-ZEMENT-SUSPENSIONEN (TESTS WITH SPECIAL MIXERS FOR GROUT CONSISTING OF WATER CEMENT SUSPENSIONS) P

Brux, G.

Zement-Kalk-Gips, vol.16, no.2, p.59-69, February 1963.
Comprehensive tests for investigating the dispersion of grouting material of various composition--including blast furnace grouting cement--in a propeller mixer, a homogenizing machine and a Colcrete double-drum mixer are described. The rheological behaviour of the mix was characterized by properties of the grout produced. The differences in chemical composition, and in grading and surface area of the cements and special cements employed are discussed.

DAS PREPAKT-VERFAHREN UND SEINE ANWENDUNG FUER UNTERWASSERUND EINPRESSBETON P

Buch, A., and Urban, J.

Beton-und Stahlbetonbau, vol.59, no.7, p.153-158, July 1964.
Prepakt concrete was developed in the U.S. and has been known for

about 40 years. It is used in places where conventional concreting is difficult or uneconomical because of the presence of groundwater, accessibility, and other factors. The author gives details about the aggregates, preparation, and applications of this concrete, and describes a mixing installation in Germany.

A NEW PRODUCT FOR CEMENTATION WORKS P

Bukowski, B.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, p.823-832.

Thin grouts now used in cementation have many essential imperfections. Probably the most important defect was its excessive slowness, usually lasting several hours. Such grouts have shown considerable sedimentation and were also unresistant against the operation of aggressive surroundings which was leading to a prompt deterioration. The improvement of the properties of grouts by using already known products did not give satisfactory effects. The addition of the Injectol to the grouts forms a new material characterized by regulated setting conditions which leaves a space of time sufficient for mixing and grouting. The material then sets very suddenly and quickly acquires a high resistance. This material does not settle and accordingly it fills up all empty crevices, caverns, etc. This material is also resistant to aggressive substances normally appearing in nature. Cementation work, performed with the new Injectol-cement material have shown that beside saving about 70 percent of the cement normally used for such works, results were obtained which so far had been impossible to reach with the previously employed methods.

NX BOREHOLE CAMERA M

Burwell, E.B., and Nesbitt, R.H.

Mining Engineering, vol.6, no.8, p.805-808, August 1954.

The use of the NX Borehole camera may disclose underground imperfections and zones of weakness in order to determine what type of grouting procedures may be necessary during construction processes.

MATERIAL PROPERTIES OF GROUTS AND OF TUFFS FROM SELECTED DRILL HOLES

Butters, S.W., Nielsen, R.R., Jones, A.H., and Green, S.J.

Salt Lake City, Utah, Terra Tek, Inc., 10 July 1974.

Rock core samples taken from exploratory drill holes at the Nevada Test Site and cast group samples were tested to determine their

mechanical and physical properties. These material properties were used for initial nuclear test site selection and in more detailed site evaluation to ensure that proper stemming and containment occurred.

NOTE SUR L'EMPLOI DE CIMENT A L'AIR COMPRIME P

Camere, M.

Annales des Ponts et Chaussees, vol.19, p.408, 1900.

CHEMICAL GROUTING-EUROPEAN TECHNIQUES C

Caron, C.

New Horizons in Construction Materials, ed. by Hsai-Yang Fang, vol.1, p.237-247. Lehigh Valley, Pa., Enro Publishing Co., 1976.
A discussion of the various types of chemical grouts and techniques used around the world, and especially in Europe.

INJECTIONS DE RESINS ORGANIQUES DANS LES FINES FISSURES DU BETON (INJECTIONS OF ORGANIC RESINS IN FINE CRACKS OF CONCRETE)

Caron, C.

Construction (Paris), Vol.19, no.4, p.103-107, April 1964.
In French.

PERENNITE DES SYSTEMES ARGILE-CIMENT OU BENTONITE-CIMENT DANS LEURS DIVERS TYPES D'APPLICATION (DURABILITY OF CLAY-CEMENT OR BENTONITE-CEMENT SYSTEMS IN THEIR VARIOUS TYPES OF APPLICATION) P, M

Caron, C.

Construction (Paris), vol.27, no.10, p.291-296, 1972.
A discussion of bentonite-cement and clay-cement grouts. In French.

RHEOLOGIE DES COULIS D'INJECTION (GROUT RHEOLOGY) P

Caron, C.

Houille Blanche, vol.25, no.5, p.453-461, 1970.
Deals with rheological behavior of visco-rigid Bingham suspensions for coarse ground, colloidal nonrigid grout for medium sand and very low viscosity pure solutions for fine sand. Reviews parameters to be considered in grouting operations. In French.

SPECIAL GROUTS: REPAIR, COMPACTION, SEALING C

Caron, C.

Annales de l'Institut Technique du Batiment et des Travaux Publics, no.261, p.1307-1318, 1969.

Discussion of two groups of grouting agents and their uses. Synthetic resins polymerized by catalysts and water-soluble monomers are used for closing cracks in structures. Monomer injection agents are used for stabilizing and sealing sandy silt soils. In French.

SPECIAL INJECTIONS: REPAIR, CONSOLIDATION, WATERTIGHTNESS C
(INJECTIONS SPECIALES: REPARATION, CONSOLIDATION, ETANCHAITE)

Caron, C.

Hanover, N.H., U.S. Army Cold Regions Research and Engineering Laboratory, Draft Translation no. CRREL-TL 551, October 1976. (Draft translation of Annals of the Technical Institute of Building and Public Works (France), no.261, p.1308-1318, September 1969.)

Discusses special injections with grouts having an organic resin base which have been developed during the past few years. These are divided into 2 main categories: precondensed resins without solvent and monomers soluble in water.

TESTS OF GROUTING GRAVEL IN RIVER BEDS P

Cartwright, H.H.

Engineering News, vol.67, no.19, p.979-984, May 8, 1913.

An investigation of the idea of injecting cement into sand and gravel in sites to make concrete without lifting, sorting, and mixing the aggregates. Results indicate concrete no better than the aggregate. The coarser the material the better. Difficulty in getting rid of excess water.

CEMENT FOUNDATION PROVES UNSUCCESSFUL FOR GROUT P

Electric Railway Journal, vol.63, p.618, April 19, 1924.

CEMENTATION METHOD OF STOPPING WATER LEAKS IN ROCKS P

Contracting and Engineering, vol.16, p.210, March 1928.

MUD PRESSURE AIDS CABLE-TOOL DRILLING M

Church, M.

Johnson Driller's Journal, vol.32, no.3, p.4-5, May-June 1960.
A field report on a method whereby hydraulic pressure is maintained on an envelope of drilling mud surrounding the well casing which lubricates the casing while it is being driven and seals the annular space.

TEORIA BASICA DO APLICACAO DE INJECOES SOB PRESSAO (THEORETICAL BASIS OF PRESSURE GROUT PENETRATION) M

Clark, B.E.

Revista do Clube de Engenharia, vol.26, no.323, p.232-235, July 1963.
Theoretical basis of pressure grout penetration; study of basic properties of grouting mixtures allows determination of changes necessary to adapt these for special purposes.

CODE OF PRACTICE FOR THE GROUTING OF TENDON DUCTS P

Hemel Hempstead, England, British Standards Institution, 1975. (Translation of Richtlinien fuer das Einpressen von Zementmoertel in Spannkanaele, Berlin, June 1973); Technical Help to Exporters THE/TRANS-131/2.
This document discusses the following information: Requirements applicable to grout composition of grout batching, mixing, and grouting; protective measures and grouting at low temperature; grout testing.

QUELQUES ESSAIS D'INJECTION AVEC DES COULIS TERNAIRES (EXPERIENCE OF GROUT INJECTIONS) P

Coen, L.

International Conference on Soil Mechanics and Foundation Engineering, 5th, Paris, July 17-22, 1961, Proceedings, vol.2, div.7, no.10, p.569-580.
The authors give the results of tests on grouting mixtures of cement, fine crushed limestone, clayey silt, and bentonite, carried out in order to determine their behavior and characteristics in average conditions of absorption in the soil to be grouted. The objectives of their research were (a) variation of the mixture, i.e. the capacity to retain the initial moisture content, because of the addition of fine aggregates to the cement; (b) the suggested time interval between preparing the mixtures and pumping them into the boreholes;

(c) the compressive strength. The tests enable the behavior of grout mixtures to be forecast when they are used in conditions similar to those of the tests. Reference is made to a practical method of grouting carried out under special precautions. The grouting of mixtures of cement-clayed silt and bentonite achieved a remarkable reduction of seepage through the impervious core of an earth-fill dam.

"PREFASIF" PREFABRICATED DIAPHRAGM WALLS

Colas des Francs, E.

Conference, Diaphragm Walls and Anchorages, London, September, 1974, p.81-87. London, Institution of Civil Engineers, 1975.

The "Prefasif" prefabricated diaphragm wall is a new development for construction of a watertight retaining wall. The established methods of diaphragm wall excavation using bentonite mud are employed. The guide walls must be carefully constructed since they must align the prefasif sections and support them in position after they have been lowered. To be sure of a good quality seal, the bentonite mud used for the excavation is replaced by a new grout which is introduced just before the installation of the prefabricated element. This method allows graduation of the characteristics of the grout according to its utilization.

COMBINATION AIR AND WATER PRESSURE GROUTING MACHINE EFFECTIVE IN FINE SAND

Engineering News-Record, vol.81, no.3, p.147, July 18, 1918.

Preliminary control and finally complete checking of artesian water rising along a line of steel sheeting were accomplished by a concrete cap and subsequent grout injection. Fine sand, ordinarily hard to grout, was cemented by special machine using alternate air and water pressure.

CONTROL OF UNDERGROUND WATER MOVEMENT

Machinery Lloyd, (Overseas ed.), vol.34, p.43-44, 13 October 1962.

Discusses jet grouting (a process for controlling the movement of water in sandy soils.)

ENGINEERING FOR DAMS M

Creager, W.P., Justin, D.D., and Hinds, J.

New York, John Wiley & Sons, 1945.

Contains chapter on grouting rock foundations and consolidation grouting.

SIMPLE AND EFFICIENT GROUTING OUTFIT P

Cropper, R.W.

Engineering News-Record, vol.93, no.4, p.149-150, July 24, 1924.
A pipe was jetted down to position and the very liquid grout (10 bags of cement in 124 gal water) was forced through jetty pipe.

CAN CHEMICAL STABILIZATION IMPROVE GROUND SUPPORT? C, G

Crow, L.J., and Kelsh, D.J.

Engineering and Mining Journal, vol.172, no.8, p.75-77, 1971.
Rock slabs of tuff sandstone were impregnated with a variety of basic monomer systems in order to determine the effect of polymer impregnation on the properties of the rock.

CYANALOC 62 CHEMICAL GROUT C, G

Wayne, New Jersey, American Cyanamid Company, Explosives and Mining Chemicals Department, October, 1962.
Cyanoloc 62 is a resinous grouting material intended for use where strength as well as waterproofing is required. It may be used in soft ground (sands and gravels) and in fractured and fissured rock formations. A supplement to AM-9 Chemical Grout, this new material is the result of continuing research to put more efficient tools into the hands of grouting specialists.

COULIS D'INJECTION ET BOUES DE GENIE CIVIL (GROUTING AND DRILLING MUDS IN CIVIL ENGINEERING PRACTICE) M

Delisle, J.P.

Bulletin Technique de la Suisse Romande, vol.89, no.24, p.397-399, November 30, 1963.
Thirty papers presented at Symposium held in London on May 22-24, 1963, under the auspices of British Society of Soil Mechanics and Foundation Engineering. Topics include general principles of grouting, application of mud in trench excavation and drilling and application of cement, chemicals and clay in grouting.

CALIFORNIA STEPS UP MUDJACKING

Dennis, T.H.

Roads and Streets, vol.86, no.8, p.40-41, August 1943.
Discusses methods and costs of program to save overloaded pavements by correcting pumping joints.

UEBER ZEMENT UND MORTELEINPRESSUNG P

Detig, W.

Beton-und Stahlbetonbau, vol.43, p.37, April 15, 1944.
Discussion of experiments dealing with injection of cement grouts into soil and joints.

EARTH PRESSURE MEASUREMENTS ON A BRACED SLURRY TRENCH WALL IN SOFT CLAY P

Dibiagio, E. and Roti, J.A.

European Conference on Soil Mechanics and Foundation Engineering, 5th, Madrid, April 1972, Proceedings, vol.1, Theme 4, p.473-483.
Observations of the earth pressure developed on a slurry-trench wall by instruments installed in one panel. Stresses in the reinforcing steel, total earth pressures, ground settlements, deflection of the wall and pore water pressure. Fifteen earth pressure cells of the vibrating-wire type were installed.

REPAIRING ABOVE-GRADE LEAKY MASONRY WALLS

Dickens, H.B.

Ottawa, Ontario, Canada, National Research Council of Canada, Report no.RN-29, July 1957.
The following techniques and materials are considered for repairing above-grade leaky masonry walls: (1) repointing of mortar joints, (2) grouting of mortar joints, (3) cement-water paints, (4) stucco coatings, and (5) silicone water repellents.

THE INJECTION OF CEMENT GROUT INTO WATER-BEARING FISSURES

Donaldson, F.

American Institute of Mining Engineers, Transactions, vol.48, p.36-40, 1914.

DOWSETT CLAIMS SUCCESS WITH MORTAR PILING P

New Civil Engineer, Institution of Civil Engineers, no.24, 1973.
A brief description is given of a pile which is formed using a high strength mortar injected under pressure into the bore during the removal of a hollow soil-filled flight auger. An intrusion aid gives the injection mortar the properties of a colloidal suspension, and prevents ground water entering the wet mortar pile, allowing its use in ground conditions where casing problems would slow down progress.

BENTONITE WITH LOW AM-9 CONCENTRATION C

Drake, J.E.

Wayne, N.J., American Cyanamid Co., March 1961.
AM-9 will gel with concentration as low as 3% bentonite.

SALT FOR SHORT GEL TIME AND LOW TEMPERATURE C

Drake, J.E.

Wayne, N.J., American Cyanamid Co., March 1962.
In application of polymer type grout (AM-9) at low temperature gel time increases. The use of NaCl attains gel times of less than one minute and is less expensive than increasing catalyst.

GROUT INTRUSION CONCRETE P

Du Plessis, J.G.

International Congress on Large Dams, 10th, Montreal, 1-5 June 1970, Transactions, vol.4, p.309-346.
The laboratory tests in support of this paper simulated the Colcrete Process which was developed in Great Britain. High-speed mixers are used to obtain an integral mix, which imparts colloidal properties to the mortar without the use of additives. This grout intrusion process is often used in dam construction.

LE PROBLEM DU TONCAGE DES PUITS SUR LE PROLONGUEMENT DU BASSIN HOUILLER DE LA SARRE EN LORRAINE

Durnerin, M.

Congress Scientifique de l'Association des Ingenieurs, Sortie de l'Ecole de Liege, 1922.

DEEP CONSOLIDATION OF GROUND BY CARBAMIDE RESIN C

Egorov, I.V.

Soil Mechanics and Foundation Engineering, no.5, p.261-265, September-October 1965. (Translation of Osnovaniya, Fundamenty i Mekhanika Gruntov, September-October 1965, p.1-3.)
Treatment of sandy soils with carbamide resin by using a 3 to 5% solution of HCl as setting agent in 8% proportion. A certain

amount of HCl must be introduced before the resin solidifies. When this acid is used as a hardener, the mixing rate must be strictly observed to control gel times. The mixing rate is also influenced by the fact that part of the acid reacts directly with soil particles. Ammonium chloride and ammonium persulfate is suggested for use to avoid these drawbacks and are mixed as 20-30% solution in amounts of 8 to 10% of the resin solution.

EPOXY GROUTS AND THEIR VARIOUS USES IN THE PULP AND PAPER INDUSTRY M

Ellis, R.L.

TAPPI Engineering Conference, Preprint, Toronto, Ont., September 28-October 2, 1975, vol.2, p.125-128, Atlanta, Ga., TAPPI, 1975.
For the pulp and paper industry, certain performance characteristics of epoxy grouts are especially important. A discussion is presented of performance data for these including: compressive strength, tensile strength, tensile-bond strength, curing time, acid resistance, shrinkage, abrasion comparison, modulus of elasticity, pour depth, pot life, etc.

DISCUSSION OF "FIELD EXPERIENCES WITH CHEMICAL GROUTING" BY M. POLIVKA, L.P. WITTE, AND J.P. GNAEDINGER C

Elston, J.P., and Kravetz, G.A.

American Society of Civil Engineers, Soil Mechanics and Foundations Division Journal, vol.83, no.SM4, Part I, p.21-26, November 1957, Paper 1430.
This paper discusses the phase of foundation treatment known as chemical grouting.

EPOXIES: THOSE WONDERFUL EPOXIES--WHAT THEY WILL AND WON'T DO M

Engineering News-Record, vol.169, no.2, p.28-30, 32, 34, 12 July 1962.
A study of what epoxies are, what they will do and won't do, with suggestions for--and warnings about--their use in construction.

IZUCHENIE KHARAKTERA TRESHCHINOVATOSTI SKAL'NYKH POROD GIDRAVLICHESKIM OPROBOVANIEM V SOCHETANII IN''EKTSIEI TSEMENTNOGO RASTVORA (STUDY OF NATURE OF JOINTING OF ROCK STRATA BY HYDRAULIC TESTING IN COMBINATION WITH CEMENT GROUTING) P

Eremeev, G.N.

Gidrotekhnicheskoe Stroitel'stvo, no.12, p.29-30, December 1966.

AERATED CEMENT GROUTING P

Esson, D.M.R.

Cement, Lime and Gravel, vol.37, p.233-234, August 1962.
Discusses the methods of using air-entrained concrete in grouting applications.

SOME APPLICATIONS OF BRITISH FULLERS' EARTH IN CIVIL ENGINEERING APPLICATIONS P

Esson, D.M.R.

Quarry Managers' Journal, vol.47, no.3, p.106-107, March 1963.

EXTINGUISHING TIP FIRES BY CEMENTATION PROCESS P

Evans, N.P.

Power & Works Engineering, vol.57, p.68-71, September 1962.
The most efficient and economical method of dealing with subterranean fires is by the use of a patented technique held by the Cementation Company, Ltd. The Cementation process consists of injecting the affected areas with special grouts, first to exclude or diminish the flow of air to material liable to oxidate, and second, to provide a medium which, in the event of combustion, will generate carbon dioxide at a steady rate so that combustion cannot be supported.

EXPANDING CEMENT P

The Engineer, vol.213, no.5549, p.977, 1 June 1962.
An expanding grout, claimed to have high compressive and high shock resisting properties, has been introduced into this country. The grout is also resistant to oils and greases. It is sold under the name of "Embeco" and is imported from the United States. "Embeco" grout consists of cement, sand, a catalyzed metallic aggregate con-

taining a water-reducing ingredient, and other agents. On placing, the initial shrinkage will occur in the first three hours, after which the grout will commence to expand and continue expanding until all points containing air have been filled. Heavy impact causes a plastic deformation of the material.

GROUND MOTION TRANSDUCER PLACEMENT SYSTEM P

Fogelson, D.J.

Kirtland AFB, New Mexico, U.S. Air Force Weapons Laboratory, Technical Report no.AFWL-TR-76-310, February 1977.
During the high explosive simulation testing, it was determined that the placement system used to install free field motion transducer canisters had discrepencies which limited the accuracy with which the canisters could be placed, and thus, affected data accuracy. Therefore, a program of evaluation was initiated to propose changes and new designs. Among the criteria used for new designs were that the device be removable from the cured grout which holds the canister in place.

CIMENTS AUX POUZZOLANES A HAUTE RESISTANCE CHIMIQUE ET DURCISSEMENT NORMAL (POZZOLAN CEMENTS OF HIGH CHEMICAL RESISTANCE AND OF NORMAL HARDENING) P

Fouilloux, P.

Revue des Materiaux de Construction et de Travaux Publics (Edition C), no.502, p.191-196, June 1957.
Applications to the manufacture of fly-ash cements. In French with brief English summary.

SUR LES TRAVAUX MINIERS PAR LES PROCEDES DE LA CIMENTATION ET DE LA SILICATISATION

Francois, A.

Congress Scientifique de l'Association des Ingenieurs, Sortie de l'Ecole de Liege, 1922.

GUIDE FOR PRESSURE GROUTING CRACKED CONCRETE AND MASONRY STRUCTURES WITH EPOXY RESINS C

Fuller, J.D., and Kreigh, J.D.

Champaign, Ill., U.S. Army Construction Engineering Research Laboratory, Technical Report no.M-9, 1973, final draft.
This manual serves as a guide for: (a) purchase, performance, and

use of materials by personnel engaged in the maintenance and repair of cracks in concrete and masonry structures, (b) to aid in the proper selection and employment of appropriate materials, equipment, and practices, (c) competent inspection and evaluation of the work done, and (d) use of proper safety precautions. The text of this guide covers both technical discussion and application procedures in order to aid the engineer in making decisions whether or not to pressure grout, and, if so, by what method. Appendix C serves as a detailed grouting procedure guide for the individuals actually performing the work.

EFFECT OF GROUT PROPERTIES ON STRUCTURAL BEHAVIOUR OF POST-TENSIONED CONCRETE BEAMS P

Geddes, J.D., and Soroka, I.

Magazine of Concrete Research, vol.15, no.44, p.67-76, July 1963.
Effect of varied properties of grout on behaviour of 18 identical post-tensioned prestressed concrete beams. Tests conducted for fluidity, bleeding, volume change, sedimentation, expansion, and cylinder compressive strength at 21 days. Beams tested to failure by 2-point symmetrical loading at 28 days. Evaluation of results.

FILTERGESETZE PLASTISCHER INJEKTIONSMASSEN BEI DER DURCHSTROMUNG VON LOCKERGESTEINEN (FLOW LAWS FOR VISCOUS INJECTION LIQUIDS IN GRAVEL)

Gelbert, K.

Veroffentlichungen des Instituts fur Bodenmechanik und Felsmechanik, Universitat Karlsruhe, no.49, 1971.
Flow laws of clays comparable to those of grouting materials are studied. In German.

GEL-TIME DATA FOR HIGH TEMPERATURES

Wayne, New Jersey, American Cyanamid Company, 10 September 1962.

A NEW FOUNDATION TECHNIQUE USING PILES SEALED BY CEMENT GROUT UNDER HIGH PRESSURE C, P

Gouvenot, D., and Gabaix, J.C.

Annual Offshore Technology Conference, 7th, Houston, Tex., May 1975, vol.2, Paper no.OTC 2310, p.645-656.
The full-scale tests carried out on steel piles have shown that the injection of cement under high pressure over the body of a pile allows one to attain very high bearing capacity, two to three times those found for a conventional pile.

INVESTIGATION OF A PLASTIC REINJECTABLE GROUT VALVE FOR USE IN BUREAU STRUCTURES P

Graham, J.R.

Denver, Colo., U.S. Bureau of Reclamation, Laboratory Report no. C-1100, June 1964.

A laboratory investigation was conducted to determine the operational characteristics of a plastic reinjectible grout valve. Concrete blocks were fabricated with the grout valves embedded then bolted together to simulate the joints found between the blocks of a dam. Tests were conducted by pumping cement grouts with different water to cement ratios into the variable width joint between blocks. Results of tests indicated that operation of this valve is somewhat unpredictable in regard to the pressures needed to open it and its resealing capabilities.

A DISCUSSION OF PRESSURE GROUTING C, P

Graham, R.W.

Colorado School of Mines Quarterly, vol.58, no.4, p.129-136, October 1963.

Discusses the field of pressure grouting as applicable to construction industry, gas industry, and the mining industry. Also discusses pressure grouting as preventive measure.

APPLICATION OF THE UNIT TAKE CONCEPT IN EVALUATING GROUT HOLE DRILLING METHODS P

Grant, L.F.

Engineering Geology, vol.1, no.1, p.52-67, January 1964.

The unit take, or quotient of volume of grout consumed divided by length of drill used for placing, can be used to rate efficiency of the grout hole. Analysis of available grouting data is complex, but it shows there are patterns of ground response for similarly treated foundations. Comparisons of summarized records are possible where the selected cases are in limited ranges of rock fracturing and weathering. Grouting curves, or split-spaced plottings of unit takes are used to illustrate the scope of grouting operations. Initial and terminal limits of grout takes are defined by these curves. Corresponding void reduction curves show the effect of grouting. Valid evaluations of different localities are based on slopes and terminal points of the curves. Ground response values show there is a substantial difference in results for grout injection through percussion-drilled holes and results for injection through diamond core drilled holes. Furthermore, it can be demonstrated that where diamond core drilling is required to complete the grouting work, percussion drilling is unnecessary.

PRIMI INTERVENTI DI RISANAMENTO, MEDIANTE INIEZIONI, CONDOTTI IN PUGLIA SU ROCCE CALCAREE FESSURATE E CARSICHE SITUATE SOTTO FALDA E SOTTO IL LIVELLO MARINO (FIRST IMPROVING INTERVENTIONS WITH INJECTIONS MADE IN APULIA ON CALCAREOUS KARST ROCKS SITUATED UNDER THE WATERTABLE AND BELOW SEA LEVEL) C, P

Grassi, D.

Geologia Applicatale Idrogeologie, vol.6, p.79-104, 1971.

The results of experiences with injections made in Apulia, Italy, on calcareous rocks containing water-bearing stratum and sea water are reported. Two examples are given concerning the waterproofing of limestone foundations of buildings. In one case, the improvement was obtained by the combined action of cement and silica gel grout in order to give the rock a perfect seal. In the other case, simple cement and bentonite grouts were used. The purpose was only to markedly reduce the permeability of the rock in order to dig easily below the water-bearing stratum. In Italian.

GROUTING AND ITS USES

Gregaire

Cement, vol.36, no.1, p.2; no.2, p.42; no.3, p.79; no.4, p.115; no.5, p.162; 1931.

Historical account of grouting as a means of strengthening walls of oil wells, mines, etc., and its value discussed. Various applications of product.

GROUT ADDITIVES FOR PRESTRESSED CONCRETE WORK P

Highways and Bridges and Engineering Works, vol.30, p.13, 18 April 1962.

Discusses the properties of grout additives, their expansion and retarding effect, design advantages, and advantages when post-tensioning. Discusses the use of Intraplast and Lubabon as additives for cement grout.

GROUT MACHINE AND GROUT GUN

Municipal Engineering, vol.52, p.206, April 1917.

GROUTING C

Water Power, vol.15, no.11, p.443-444, November 1963.

Discussion of recent research using silicates, other chemical grouts, and liquid grouts; also deployment of grout curtains.

GROUTING ALTERNATE HOLES REDUCES DRILLING TIME P

Engineering Record, p.479, October 14, 1916.

GROUTING AS A METHOD OF ENGINEERING CONSTRUCTION P

Engineering and Contracting, vol.45, p.21, January 13, 1915.
Consideration of mixtures for grouting and costs. Practice indicates failure in attempt to grout fine sand. Rock takes grout satisfactorily. Practice since 1905.

GROUTING GRAVEL IN RIVER BEDS P

Engineering News, vol.69, no.19, p.969-970, May 8, 1913.
Discusses history of grouting experience in building dams and bridge piers on river beds.

THE GROUTING OF CRACKS WITH SYNTHETIC RESINS

Muswell Hill, England; British Railways Research Department, Chemical Research Division, Report no. CR 34, February 1967.

GROUTING OF HORIZONTAL HOLES IN COALBEDS

Duncan, Okla., Halliburton Services, Research Report, 1971-1972, BuMines-OFR-13-72, 4 May 1972.
This report, prepared under contract for U.S. Bureau of Mines, describes research to evaluate materials and develop a new technique for packing holes in which a semiliquid and/or rigid type grout could be placed in the hole to provide satisfactory sealing. Recommendations included: (a) grouting pressure should not exceed 0.4 psi/ft times feet of overburden , (b) mine water and actual grouting materials to be used should always be checked for setting times before the grout job, (c) the packer system as designed should be used in 3-inch horizontal holes with either the semi-liquid or rigid-grout materials, (d) the rigid grout tested using a salt-saturated portland-gypsum-cement blend was satisfactory for use in boreholes of coalbeds.

GROUTING OF PRESTRESSED CONCRETE (REPORT OF A ONE-DAY SYMPOSIUM OF THE PRESTRESSED CONCRETE DEVELOPMENT GROUP)

Roads and Road Construction, vol.40, p.136-139, May 1962.

GROUTING OPERATIONS. CATSKILL WATER SUPPLY P

American Society of Civil Engineers, Transactions, vol.83, p.980, 1920.
Discussion of general subject of grouting, examples under various conditions.

GROUTING: PRINCIPLES OF GROUTING; GROUTING-PRACTICAL APPLICATIONS P

New Zealand Concrete Construction, vol.19, no.2, p.8-16, April 1975.
Gives history, basic techniques, types of grout, injection techniques. Also discusses prestressing ducts, ground anchors, grouted concrete, rock strengthening, soil strengthening, soil stabilization and repair of structures.

GROUTING REINFORCES ROCK AT OAK GROVE SURGE CHAMBER

Engineering News-Record, vol.95, no.19, p.746-749, November 5, 1925.
Novel extensometers for test during work in tunnel.

GROUTING UNDER WATER P

Concrete Construction, vol.6, no.2, p.38, February 1961.
A Florida contractor has developed a successful technique for underwater cement grouting for the purpose of stopping leaks in the countless miles of seawall which must be maintained for waterfront properties. His method is to use a proprietary accelerating admixture in combination with portland cement and sand to produce an extremely fast setting, dense grout which will not shrink away from the sides of the crack being prepared, or experience the leaching away of cement paste due to the action of the water.

GROUTING WITH BENTONITE TO PREVENT SEEPAGE M

Compressed Air Magazine, p.5085, July 1936.
Brief reference to article in Mining Trade Notes describing Forest Service tests with "Volclay."

GROUTING WITH ORGANIC COMPOUNDS C

Mining Journal, vol.258, p.444-445, 4 May 1962.
AM-9 chemical grout is offered as a commercial product by American Cyanamid Co. and is said to represent a new concept in the fields of soil stabilization and grouting. The product is a mixture of two organic monomers, acrylamide and N.N.-methylene-bisacrylamide in proportions which, when properly catalyzed, produce very stiff gels from dilute aqueous solutions.

GROUTS FOR PRESTRESSED CONCRETE

Architect and Building News, vol.221, no.4, p.132, 24 January 1962.

THE CHARACTER OF PERCOLATION THROUGH ROCK MASS AS OBSERVED WHEN INVESTIGATING FOR DESIGN OF THE CUT-OFF P

Guerra, J.R., Weyermann, W.J., and Mota, O.S.

International Congress on Large Dams, 9th, Istanbul, 1967, Transactions, vol.1, p.109-122.

Test data from drilling and water test programs from bore holes at several Portuguese damsites were used to design a grouting program. Discusses interpretation of the data and results of the grouting operations.

GUIDE FOR USE OF EPOXY COMPOUNDS WITH CONCRETE M

American Concrete Institute, Proceedings, vol.59, no.9, p.1121-1142, September 1962.

Describes proper procedures for the use of epoxy resin compounds for skid-resistant overlays, waterproofing, patching, crack and joint sealing, bonding new concrete or hardened concrete to old concrete, grouting, coatings to prevent chemical attack and other uses. Methods of surface preparation of both concrete and steel, removing contamination prior to applying epoxy compounds, and for applying the epoxy resin compound are described.

GUIDE SPECIFICATIONS FOR CHEMICAL GROUTS C

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.94, no.SM2, p.345-352, March 1968, Paper 5830.

The guide specifications which follow are intended to make it possible for the specifying engineer to obtain the chemical or chemicals desired, and to effect grouting operations intended with these materials. For the purpose of these specifications, grouts are considered to be any material which may be pumped or placed into the voids in a formation to change the formation properties. Chemical grouts are defined as true solutions, which contain no suspended solid particles unless those are deliberately added for some specific purpose. It is anticipated that in a specification for a particular job it may be necessary to revise and enlarge some of these sections.

HALLIBURTON PRESSURE GROUTING SERVICE P

Duncan, Okla., Halliburton Co., Technical Data Sheet PGS-0003, February 1961.

Herculox--great affinity for siliceous surfaces, not soluble in chemicals generally present in underground water; works best when solidifying weak, sandy soils; and will not set properly in calcareous soils.

Technical Data Sheet PGS 0004, July 1961.

Doc. Grout--works best in controlling severe conditions of flowing underground water, kerosene, and oil; powder and solution forms are toxic; works best in water control in fine underground sands.

Technical Data Sheet PGS 0008, November 1961.

Blox--all grout--insoluble in water, kerosene, and oil; under non-dehydrating conditions the gel is very stable, under dry conditions the gel will cause shrinkage.

GROUT TREATMENT METHODS

Hammond, R.

Muck Shifter, vol.23, p.33-36, January 1965.

FLOW CHARACTERISTICS OF GROUTS FOR PREPACKED CONCRETE P

Harada, Y., and Iwai, Y.

Railway Technical Research Institute, Quarterly Reports, vol.12, no.3, p.144-148, September 1971.

GROUTING FOR LARGE CAPACITY TENDONS FOR NUCLEAR CONTAINMENT STRUCTURES P

Harstead, G.A., and Kummerle, E.R.

American Society of Civil Engineers, Annual and National Meeting on Structural Engineering, Pittsburgh, Pennsylvania, September 30-October 4, 1968, Preprint 743.

Describes testing program which employs range of tendon sizes in sequence of tests defining effectiveness of normal grouting procedures, developing special procedures, and demonstrating reproducibility of effective procedures under field conditions.

LABORATORY VERIFICATION OF EXPLOSION CALCULATIONS; PART III: GROUT, A ROCKLIKE LOCKING SOLID P

Hearst, J.R., and others

Livermore, Calif., University of California, Lawrence Radiation Laboratory, UCRL-12065, Part III, April 1970.

Spherical explosions in grout, a locking solid with properties similar to those of rock, have been compared to computer calculations. It was necessary to introduce a strain-rate-dependent term in the calculation of deviatoric stress to obtain agreement between calculation and experiment. Measurements of radius of multiple cracking and of free surface velocity agreed well. Measurements of stress, whose validity is not certain, agreed fairly well at stress levels between 0.4 kb and about 10 kb; below 0.4 kb agreement was not as good.

TRAGVERHALTEN VON VERPREBAUKERN (BEARING CHARACTERISTICS OF INJECTED TIEBACKS)

Herbst, T.F.

Budapest Conference on Soil Mechanics and Foundation Engineering, 4th, Budapest, October 1971, Proceedings, p.601-615. Budapest, Akademia Kiado, 1971.
The bearing characteristics of injected tiebacks transferring their traction force into the soil by means of adhesion between steel and grout can be explained in two ways. Shear failure may occur either along injected mass and soil, or along the steel anchor. In German.

CEMENT GROUTING P

Heynes, R.F.

Concrete, vol.8, no.1, p.43-45, January 1974.
Discusses conventional cement grouting, problems and specialized techniques.

STUDIES ON ADMIXTURES OF CEMENT GROUT FOR FILLING FINE VOIDS C, P

Higuchi, Y.

Japan Society of Civil Engineers, Transactions, no.81, p.27-50, May 1962.
Surveys history of cement and chemical grouting. Successful treatment of cracks by combining cement and sodium silicate. Recommendations for using quick-setting cement grout and expansive grout. In Japanese with English abstract.

GROUT SELECTION: A NEW CLASSIFICATION SYSTEM P

Hilton, I.C.

Civil Engineering and Public Works Review, vol.62, no.734, p.993-995, September 1967.

A classification system for grouts is proposed based on flow characteristics and on the properties of the set grout. It provides for the selection of grouts by consideration of the permeability of the soil to be treated and the required strength and reduction in permeability.

EMERGENCY GROUTING WITH SULPHUR M

Holley, C.E.

Engineering and Mining Journal, vol.107, p.279, February 8, 1919.

THE PENETRATION OF GROUTING FLUID INTO FISSURED ROCK P

Holzlohner, U.

Rock Mechanics, vol.2, no.1, p.41-60, 1970.
Investigation of the penetration of grouting fluid from a bore hole into a rockfracture--assuming a horizontal fracture which is intersected by a vertical bore hole. Results of the theory can be used in engineering practice.

AVERAGE COMPLETION COST IS 20 PERCENT OF TOTAL WELL COST P

Huber, T.A., Allen, T.O., and Abendroth, O.F.

Oil and Gas Journal, vol.49, p.234, November 16, 1950.
Contains a discussion of special cements used in grouting.

GROUTING AND SEMIGROUTING WITH COLD EMULSIFIED BITUMEN M

Hughes, A.C.

Surveyor, vol.87, no.2257, p.537-538, April 26, 1935.
Early experiments, procedure in Hampshire, nature and laying of road stone; grouting road stone; applying sealing coat; costs and statistics.

HIGH STRENGTH CEMENT GROUTS

Hughes, B.P.

Concrete (London), vol.9, no.10, p.31-32, October 1975.
This development work on grout is shown to include jointing and repairs to structural members. The effects of variations in ratio, additive type and amount, and inclusion or not of an aggregate on grouting efficiency and strength are considered.

EXPERIENCES IN PRESSURE GROUTING LEAD TO HYDRAULIC MACHINE

Hulse, S.C.

Engineering News-Record, vol.87, no.2, p.74-76, July 14, 1921.

LIME GROUT PENETRATION AND ASSOCIATED MOISTURE MOVEMENTS IN SOIL M

Ingles, O.G., and Neil, R.C.

Victoria, Australia, Commonwealth Scientific and Industrial Research Organisation, Division of Applied Geomechanics, Research Paper no.138, 1970 (presented as Paper no.2871 of the Symposium on Soils and Earth Structures in Arid Climates, Adelaide, 21-22 May 1970).
Series of field experiments made to permit a rational assessment of the use of lime process for deep soil stabilization for design purposes. Results and practical application are evaluated.

INJECTING GROUT WITH DIAPHRAGM PUMPS

Engineering News, vol.72, no.21, p.1030, November 19, 1914.
Some Boston contractors had trouble with pneumatic placing, so used a hand-operated diaphragm pump shown in cross section. Very brief article.

DANISH EXPERIMENTS ON FREEZING OF GROUT P

Ipsen, J.

Federation Internationale de la Precontrainte, Third International Congress, 1958, Session II, Paper no.3, vol.1, p.313-322.
Brief discussion of grouting of water-filled ducts.

DASA ROCK STUDY M

Isbell, W.M., Shipman, F., and Jones, A.H.

Santa Barbara, Calif., GM Defense Research Laboratories, Progress Report no.5, August 1966.
During the reporting period the Hugoniot Equation of State of WES 44 D grout was measured and compared with data measured by Waterways Experiment Station.

OPREDELENIE GIDRAVLICESKICH SOPROTIVIENIJ PRI DVIZENII VJAZKO-PLASTICESKICH ZIDKOSTEJ V TRESCINACH GORNYCH POROD (DETERMINATION OF HYDRAULIC RESISTANCE TO FLOW OF VISCO-PLASTIC FLUIDS THROUGH ROCK FISSURES)

Ivacev, L., Kipko, E., Polozov, J., and Salamatov, M.

Izvestija Vuzov Gornyj Zurnal, vol.15, no.5, p.47-49, 1972.
Discusses theoretical problems of the flow of visco-plastic fluids in fissures of rocks. Using the generalized Reynold's criterion, the flow regime and hydraulic resistance arising in grouting such fluids into the fissured rock can be established. In Russian.

AN EXPERIMENTAL STUDY ON UTILIZATION OF COHESIVE CLAY FOR GROUTS P

Iwata, M.

Japan Society of Civil Engineers, Transactions, vol.3, pt.2, p.250-251, November 1972. (Unabridged version of this paper in Japanese appears in Japan Society of Civil Engineers, Proceedings, no.195, p.89-99, November 1971.)
A study of the physico-chemical behavior of the clay in the system of the clay-cement-grout. Experiments included the proportioning and "economical" pulverizing of the clay when the volcanic cohesive clay, existent widely in Japan, is to be used for grouting. In the proportioning, part of the cohesive clay was substituted by bentonite.

CHECKING THE QUALITY OF CEMENT GROUTING IN ROCKS BY ULTRASONIC METHOD P

Jamscikov, V.S., Bondarenko, V.G., and Scetinin, V.A.

Sachtnoe Stroitel'stvo, vol.14, no.5, p.14-15, 1970.
Measurements of the velocities of longitudinal and transversal elastic waves by an ultrasonic transmitter show that the grouted rock becomes more compact and the velocity of the elastic waves increases in relation to the original state.

JAPAN, CITING POISON CASES, BANS ALL GROUT BUT SILICON C

Engineering News-Record, vol.193, no.4, p.14, July 18, 1974.

CONTRIBUTION TO CORRELATION OF CEMENT ABSORPTION AND LOSS OF WATER IN PRESSURE TESTS FOR FLYSCH ROCKS P

Jawanski, W.

International Society of Rock Mechanics, Second Congress, Belgrade, 1970, Proceedings, no.16, Theme 6, p.241-246.
The correlation of cement absorption in relation to the loss of water in pressure tests before grouting is analyzed. Kind of grout, grouting pressure, and leaks of grout are other factors which should be taken into consideration in predicting cement absorption.

INJECTION MATERIALS FOR FOUNDATION SOIL AND THEIR BEHAVIOUR DURING INJECTION P

Jessberger, H.L.

VDI-Zeitschrift, vol.112, no.3, p.181-186, 1970.
Survey of the injection materials, various theories relating to injection, injection programs, the consumption of injection material and the calculation of injection costs in subsoil injections in sealing or stabilizing an area treated by systematic interaction of the subsoil and the materials injected.

JET-GROUT RIG DIGS HOLE THEN CONCRETES IT ON WAY UP P

Engineering News-Record, vol.169, no.21, p.42-43, November 22, 1962.
Test of new method; high-speed jets of water are followed with thin grout.

GROUT INVESTIGATION FOR SHEAR STRINGER ZONE AT UKAI DAM, INDIA P

Jethva, P.P.

Indian Geotechnical Journal, vol.1, no.2, p.143-151, 1971.
Describes the composition and production of the grout and laboratory tests. Studies of the influence of the components of the mixture on its bleeding, setting time, viscosity, and strength.

GROUTING OF POST-TENSIONED PRESTRESSED CONCRETE P

Johansen, R.

RILEM (Reunion Internationale des Laboratoires d'Essais et de Recherches sur les Materiaux et les Constructions) Bulletin no.13, new series, p.9-23, December 1961.
This article reviews the main points of view that exist and discusses the problems of grouting on the basis of the experimental work

presented at this symposium. The first part deals with the requirements for the grout properties, and the factors influencing these. In the second part are treated the different components of the grout and their influence on the grout properties. The third part describes the most important requirements for the injection of the building site. Finally, structural requirements for the ducts are considered in order to achieve the most successful injection.

FIELD TESTS OF GROUTED ROD ANCHORS IN PERMAFROST

Johnston, G.H., and Ladanyi, B.

Canadian Geotechnical Journal, no.2, p.176-194, 1972.
The field study of grouted pile anchors in permafrost undertaken at two sites in Northern Manitoba was designed to investigate the time-dependent behavior of anchors subjected to uplift loads less than those causing rapid failure.

NEW AND CONVENTIONAL ENGINEERING USES OF FLY ASH

Joshi, R.C., Duncan, D.M., and McMaster, H.M.

American Society of Civil Engineers, Transportation Engineering Journal, vol.101, no.TE4, p.791-806, November 1975, Paper 11730.
Successful uses of pozzolanic fly ash for modification of a highly plastic clay, and of natural and stabilized fly ashes to effect economy in road construction, are described. Laboratory investigations were conducted on three fly ashes to determine suitability of natural fly ash for structural fill, and lime and cement stabilized fly ashes for base course construction.

AGING TESTS AM-9 CHEMICAL GROUT C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., February 1963.
Five-year tests indicate no gel deterioration as related to gel strength.

AM-9 ADMIXTURE FOR CEMENT C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., January 1961.
Laboratory tests on 50 cylinders; addition of cement increased the AM-9 psi; the author recommends 60-65 lbs of cement per 30 gals of solution, with bentonite as a dispersant.

AM-9 CHEMICAL GROUT COST ESTIMATE FOR CONSTRUCTION AND MINING C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., January 1962.
Cost charts on cost per yard of stabilized soil based on void ratio; penetration related to grout volume. Determination of grout hole spacing.

CATALYTIC EFFECT OF METALS C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., August 1963.
A clean surface of-copper, brass, or iron, will build up a contact gel film in about half the normal gel time; a coating of heavy oil or grease will prevent such buildup. Large vessels can be protected with aluminum paint.

CHEMICAL GROUT C, P

Karol, R.H.

Colliery Guardian, vol.203, p.230-235, August 1961.
Comparison of methods and merits of AM-9 with portland cement; properties, gel times, emplacement methods, and general economics.

CHEMICAL GROUTING TECHNOLOGY C

Karol, R.H.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.94, no.SM1, p.175-204, January 1968, Paper 5748.
Grouting in various formations discussed (lab conditions). Discussion of chemical grouts in curtains and various grouting patterns.

DYE TRACERS M

Karol, R.H.

Wayne, N.J., American Cyanamid Co., January 1960.
Contrasting colors are recommended in testing dyes that come to the surface--in underground work flourescent dyes and a black light simplify detection.

FIELD PROCEDURES FOR STOPPING SURFACE LEAKAGE C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., November 1960.
Technique to cut off surface backflow of chemical grout is intermittent pumping based upon gel time. Pumping is started prior to gel time; several cycles will prove successful in most instances. Gel time must be known.

GEL CHARTS FOR HIGH TEMPERATURE C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., December 1963.
Gel charts are revised to high temperatures. The revision encompasses the use of more effective buffer solutions in smaller quantities. The chart shows gel time and temperature ranges of the various catalyst systems present.

GEL EXTRUSION FROM GROUT HOLES C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., February 1963.
The extrusion of gel from a grout hole is evidence that the degree of water shutoff is less than 100%; suggestions for eliminating the problem.

GENERAL SPECIFICATIONS FOR FIELD USE OF AM-9 CHEMICAL GROUT C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., September 1963.
A guide for preparing the engineering specifications for a grouting problem.

GROUT COSTS P

Karol, R.H.

Wayne, N.J., American Cyanamid Co., November 1963.
Real cost is in-place cost which includes cost of raw materials, drilling, pumping labor, and supervision. Comparison of in-place costs of AM-9 (polymer) and cement.

GROUT CURTAINS SHORT GEL TIME IN FLOWING GROUND WATER C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., March 1961.
A summary of laboratory experiments to determine the relationship between gel times and pipe pulling time in a stratified deposit with flowing water. Reaffirms idea of using very short gel times for grout curtains in granular deposits.

GROUT VISCOSITIES C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., March 1963.
Tests were made on viscosity measurements and flow resulting in this conclusion: the rate at which solution grouts can be pumped into a formation will vary inversely with the grout viscosity and directly with the pumping pressure.

GROUTING IN DRY SANDS C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., October 1962.
Tests have shown that AM-9 grouting in dry sands is effected only with using a combination of excess catalyst and short gel time; recommended gel time is one minute and catalyst concentration not less than 1% AP and 0.8% DMAPN.

MINIMUM MONOMER CONCENTRATION FOR GEL FORMATION C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., February 1963.
Straight-line relationship between temperature and monomer concentration; the higher the temperature, the higher the monomer concentration. There is no consideration of effect of chloride in solution which might alter this relationship.

PHYSICAL PROPERTIES OF CHEMICAL GROUTS C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., November 1963.
List of major types of chemical grout; viscosity, gel time, range, specific gravity, and strength given for each type.

PROCEDURE FOR CHECKING GEL TIME C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., December 1963.
Experimental laboratory procedure for determining gel times.

PUMPING EQUIPMENT FOR CHEMICAL GROUT C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., January 1963.
Pump arrangements for pumping 0.2 to 12 gallons of grout per minute at pressures up to 1000 psi. Grout was AM-9.

SHORT GEL TIMES WITH LONG PUMPING TIMES C

Karol, R.H.

Wayne, N.J., American Cyanamid Co., April 1961.
Main advantage of AM-9 is that it can be pumped for a period far in excess of the gel time.

MATERIALS AND PROCEDURES FOR THE REPAIR OF SPALLS IN CONCRETE M

Kemphues, R.F.

Champaign, Ill., U.S. Army Construction Engineering Research Laboratory, Technical Report no. CERL-TR-M-40, March 1973.
Old and new materials used for repairing damaged or deteriorated concrete are studied and evaluated. Results indicate that large damaged areas can be successfully and economically repaired using a good quality, low slump, portland cement concrete bonded to the old concrete with an epoxy resin grout.

SYMPOSIUM ON GROUTING: RESEARCH IN FOUNDATION GROUTING IN CEMENT P

Kennedy, T.B.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundation Division, vol.87, no.SM2, Part 1, p.55-93, April 1961, Paper 2791.
Laboratory and field tests demonstrate the advantages and disadvantages of cement grout. Grouting techniques and types of equipment used in these tests are described.

PRACTICAL APPLICATIONS OF INTRUSION GROUT MIXED-IN-PLACE PILES

King, J.C., Liver, N.L., and Mardorf, E.C.

Roads and Engineering Construction, vol.92, no.10, p.105-111, October 1954.
Describes process used on difficult foundation stabilization problems; procedure consists of injecting intrusion grout through hollow shaft to rotating mixing head.

INVESTIGATION OF POROUS STRUCTURE AND IMPERMEABILITY OF COLLOIDAL CEMENT PASTES AND GROUTS P

Klimanova, A.F., Dubnikov, L.M., Ur'ev, N.B., and Mikhailov, N.V.

Hydrotechnical Construction, no.5, p.404-408, May 1970. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.5, p.15-18, May 1970.)
This paper discusses how various elements of the technology of preparation of colloidal cement adhesive (pregrinding of the cement, vibroactivation of the mixture, and addition of various amounts of quartz microfillers) affect its pore structure and waterproofing qualities. The experimental data show that CCA and CCS can be successfully used as waterproofing materials.

APPLICATION OF SEISMIC METHODS IN THE PREDICTION OF GROUT TAKE IN ROCK

Knill, J.L.

Conference on In Situ Investigations in Soils and Rocks, May 13-15, 1969, Proceedings, p.93-100. British Geotechnical Society, 1970.

CAVITATION EROSION OF CEMENT GROUTS C, P

Koida, N.U., and Bobrovskii, E.A.

Hydrotechnical Construction, no.10, p.954-960, October 1975. (Translation of Gidrotekhnicheskoe Stroitel'stvo, no.10, p.24-27, October 1975.)

STATE-OF-THE-ART: ULTIMATE AXIAL CAPACITY OF GROUTED PILES

Kraft, L.M., and Lyons, C.G.

Sixth Annual Offshore Technology Conference, Houston, Texas, May 6-8, 1974, Preprints, vol.2, p.485-504.

A state-of-the-art review is presented of information on design, installation, and performance of grouted piles. The influence of stress relief, moisture migration, mechanical disturbance, and drilling mud on the development of skin friction is discussed.

A CONTRIBUTION TO THE INVESTIGATION OF THE PRESSURE GROUTING EFFECT ON CONSOLIDATION OF ROCK MASSES P

Kujundzic, B.

International Society of Rock Mechanics, 1st Congress, Lisbon, 1966, Proceedings, vol.2, p.633-638.
Surveys methods used for checking the effect achieved by consolidation grouting. Discusses methodology for quantitative determination of this effect. Gives method for separating the consolidation effect due to the prior loading of the rock mass in the course of the pressure test from the effect achieved by the grouting only.

REMARQUES SUR LA FILTRATION DES COULIS DE CIMENTS (REMARKS ON FILTRATION OF CEMENT GROUT) P

Lamballerie, G. de.

Chimie & Industrie, vol.93, no.2, p.166-172, February 1965.
Describes laboratory studies on dehydration process in filtration of cement grout. Discusses effects of parameters of filtering medium or grout composition and operational conditions.

TERRANIER CHEMICAL GROUT C

Lamberton, B.A.

American Society of Civil Engineers, Structural Engineering Conference--Preprint 517, May 8-12, 1967.
Chemical grout manufactured by Rayonier successfully used by contractor. Product of wood chemistry. It is a finely-divided dark brown powder. Described chemically as polyflavonoid or polyphenol. Most commonly used concentration is 25%. Results of tests and field experience.

CONTROL OF CONSOLIDATION BY GROUTING; CONVENTIONAL AND GEOPHYSICAL METHODS

Lebegue, Y.

International Congress International Association Engineering Geology, Paris, 1970, Proceedings, vol.1, p.283-294.
Some examples are described of the different methods for studying the improvement of the mechanical properties of a medium consolidated by grouting. Indications are given of recent developments in the use of geophysical methods.

CLAYS FOR CLAY GROUTING M

Leonard, M.W., and Dempsey, J.A.

Grouts and Drilling Muds in Engineering Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, May 1963, ed. by A.D.M. Penman, p.119-126. London, Butterworths, 1963.

A discussion is given of the choice of clays for clay grouting, and it is shown that the specification of the result to be achieved by a clay grout is more significant than the properties of the clay itself. The conclusion is reached that natural clays are preferred to prepared clays wherever possible.

CONCRETE CRACKS - A STATEMENT AND REMEDY M

Letman, J.A., and Hewlett, P.C.

Concrete, vol.8, no.1, p.30-34, January 1974.

Discusses a technique known as the Cementation Chemicals Bonding Process for the repair of cracks using resin injection.

INVESTIGATIONS INTO THE INTRODUCTION OF SOLID MATERIALS INTO VOID SYSTEMS WITH REFERENCE TO GROUTING TECHNOLOGY C

Leussink, H., and Muller-Kirchenbauer, H.

Essen, Vortrage Baugrundtagung der Deutschen Gesellschaft fur Erd-und Grundbau, 1969, p.185-207.

Experimental investigations to determine the range of plastic and chemical grouting materials in loose soil is presented in an interim report. In order to consider errors in theoretical calculations, the results of measurements are compared with calculations and nomograms. There was very good agreement between theory and experiment. The investigations are being continued.

INTERNAL EROSION AND COLMATATION IN POROUS MEDIUM (MATHEMATICAL MODEL) C, P

Litwiniszyn, J.

International Symposium on Rock Mechanics, Madrid, 22-24 October 1968, Proceedings, p.383-388. Madrid, Editorial Blume, 1970.

Discussion of the phenomenon of suspension flow in a porous medium. Describes changes due to the trapping of suspended particles by porous medium--the colmatage phenomenon and the breaking away of particles of this medium--the internal erosion phenomenon or suffosion process. Grouting researchers may be interested in the system of equations and solution obtained.

BARRAGE ET GEOLOGIE

Lugeon, M.

Bulletin Technique de la Suisse Romande (Lausanne), vol.58, p.225-240, 1933.

STRATA INJECTION AT LANGANNET

MacGregor, W.

Colliery Guardian, vol.213, p.617-621, November 1966.
Method used in mine construction in Fife, Scotland.

MAINTENANCE PRACTICES FOR RIGID PAVEMENTS P

American Society of Civil Engineers, Journal of the Aero-Space Transport Division, vol.94, no.AT-1, p.57-82, November 1968, Paper 6253. (See especially p.77-81, Slabjacking.)
Slabjacking consists of maintaining or correcting the crown and profile of a concrete pavement by injecting a grout under the slab. The grout fills the voids under the slab, thereby restoring uniform support.

CEMENTATION OF BITUMINOUS-COALMINE ROOF STRATA; INJECTION OF EPOXY AND POLYESTER-TYPE RESINS M

Maize, E.R., and Oitto, R.H.

Washington, D.C., U.S. Bureau of Mines, Report of Investigations 5439, 1959.
Epoxy and polyester-type resins were injected into coal-mine roof strata of the thick Freeport coal seam in Allegheny County, Pa. at test sites in roof that had been exposed several weeks, in newly exposed roof, and in strata over solid coal. Test results indicate that the method of strengthening bituminous-coal-mine roof by injecting a bonding material into the roof strata can be developed into a safe, efficient support system. Only extensive experimentation in various coal beds will determine whether roof bonding will become a standardized method of roof support or if it can be effective when used with other types of roof support.

MAJOR NEW METHOD OF BRICK CONSTRUCTION BEGAN IN LOS ANGELES

Brick and Clay Record, vol.141, no.1, p.42-43, July 1962.

THE FLOW PROPERTIES AND YIELD GRADIENTS OF BENTONITE GROUTS IN SANDS AND CAPILLARIES M

Marsland, A., and Loudon, A.G.

Grouts and Drilling Muds in Engineering-Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, May 1963, ed. by A.D.M. Penman, p.15-21. London, Butterworths, 1963.
Laboratory studies of bentonite grouts, pumpability, and penetrating properties.

ENGINEERING PROBLEMS IN ROCK CONTAINING PYRRHOTITE

Martna, J.

International Symposium on Large Permanent Underground Openings, Oslo, 1969, Proceedings, p.87-92. Oslo, Universitetsforlaget, 1970.
Permeable rocks containing pyrrhotite should be avoided in construction of large underground openings. If this is not possible, protective measures must usually be taken. Concrete or shotcrete linings made with sulphate-resistant cement have been used. The lining may be combined with grouting, or an insulating layer between the rock and the lining.

MASS CONCRETE PROBLEMS DISCUSSED AT MEETING

Engineering News-Record, vol.108, no.16, p.588-589, April 21, 1932.
Grouting tests by University of California.

MODERN GROUTING TECHNIQUES M

Mayer, A.

Grouts and Drilling Muds in Engineering Practice; Symposium organized by the British National Society of the International Society of Soil Mechanics and Foundation Engineering at the Institution of Civil Engineers, May 1963, ed. by A.D.M. Penman, p.7-9. London, Butterworths, 1963.
General discussion of methods of research into, and control of, grouting which have been developed in recent years.

APPLICATION OF WATER JET CUTTING TECHNOLOGY TO CEMENT GROUTS AND CONCRETE P

McCurrich, L.H., and Browne, R.D.

International Symposium on Jet Cutting Technology, First, University of Warwick, Coventry, England, April 1972, Paper G7, p.69-91.

Mechanisms for cutting and demolishing concrete by water jets. Proposes a method of presenting data on a water jet performance chart. Gives experimental results for drilling cement grouts and cutting concretes.

PRIME ESPERIENZE DI CONTROLLO IN SITO CON SONE A RADIOISOTOPI DEGLI INTERVENTI DI MIGLIORAMENTO DELLE ROCCE (FIRST EXPERIENCE WITH NUCLEAR DEVICES FOR MEASURING THE PERFORMANCE OF WATERTIGHT GROUTS IN ROCKS) P, M

Melidoro, G., and Pirastru, E.

Geologia Applicata e Idrogeologia, vol.7, p.13-29, 1972.
The principles of nuclear devices and the special problems of calibration are reported. These consist of the elimination of the interference due to the particular chemical composition of cement and bentonite in the grout. In Italian.

THE ART OF PRESSURE GROUTING P

Minear, V.L.

Reclamation Era, vol.23, p.56-58, March 1937.
Popular article based on Bureau of Reclamation Technical Memorandum 535.

DEVELOPMENT OF CEMENTITIOUS GROUTS FOR THE INCORPORATION OF RADIOACTIVE WASTES. PART 2: CONTINUATION OF CESIUM AND STRONTIUM LEACH STUDIES P

Moore, J.G.

Oak Ridge, Tenn., Oak Ridge National Laboratory ORNL-5142 (Part 2 of ORNL-4962), September 1976.
Additional leach studies were completed on the leachability of cesium and strontium from simulated hydrofracture grout. These studies followed the test method proposed by the International Atomic Energy Agency or a modification which exposed smaller specimens with a higher surface-to-volume ratio to a larger volume of leachant. The results showed that the amount of cesium or strontium leached from the grout varied directly with the degree of drying during curing and inversely with the time of curing. The leachability also depends on the composition of the leachant and varies in the order: distilled water > tap water > grout water.

WORLD'S LARGEST GROUT CURTAIN IS BUILT AT -50° P

Nairne, Virginia

Engineering and Contract Record, vol.74, no.2, p.76-78, February 1961.

Underground grout curtain reaches depth of 200 ft. The curtain consists of a single row of grouted 2-in. holes spaced at 5-foot intervals. Each hole is drilled and grouted in four sections. Grout pressure is increased as the depth increases. The grout is pumped into a hole until the surrounding ground has taken the required amount. Then the hole itself is flushed. After the four sections have been completed, the full depth of the hole is filled with grout.

USE OF LOGGING TO DETERMINE THE INFLUENCE OF BLASTING ON THE PERMEABILITY OF CLAY-CEMENT GROUT CURTAIN P

Necas, J., Tkany, Z., and Valtr, V.

Vodni Hospodarstvi, vol.7, no.7, p.189-193, 1969.

A review of the research to determine the influence of blasting operations on the grout curtain on construction sites in the Carpathian flysch. The influence of blasting upon the grout curtain and the change in its permeability was determined by means of water pressure tests and different geophysical measurements in test bore holes.

NEUARTIGE INJEKTIONSARBEITEN IN FRANKREICH UND IN DER SCHWEIZ (NEW PRESSURE GROUTING METHODS IN FRANCE AND SWITZERLAND)

Tiefbau, vol.9, no.3, p.167-169, March 1967.

NEW GROUTING METHOD SPEEDS INSTALLATION P

Steel, vol.109, p.98, July 7, 1941.

Discussion of merits of "Groutex" in patching and repairing concrete and for emergency use.

NON-SHRINK GROUT AND MORTAR (EMBECO PRODUCTS) P

Cleveland, Ohio, Master Builders Company, Ltd., 1969. General Catalog; Section 3.

Discusses evolution of Embeco products, why Embeco is needed, other advantages, standard and special formulations, recommended applications, directions for use and suggestions on procedure, and service aids. Products are Embeco Grout (pre-mixed), Special Embeco Grout

with 3/8" aggregate (pre-mixed), Embeco Mortar (pre-mixed), Embeco Aggregate, Embeco No.5, and Metallic Waterproofing. Recommended applications are precision grouting of machinery, grouting anchor bolts and dowels, grouting structural columns, grouting bearing plates, grouting foundation underpinning, caulking between precase panels and around pipes through foundation walls, repairing cracks in concrete, caulking joint between floor slab and foundation wall, repairing concrete floors, ramps, platforms (areas less than 12" in diameter), producing non-shrink concrete, repairing holes and cracks, plaster coating spalled areas, gunned mortar, plaster coating foundation walls, topping for resurfacing floors, brushcoat waterproofing treatments, setting floor brick with thin joints, and pressure grouting with close clearances.

GROUTED CUTOFF CURTAINS IN FISSURED ROCK P

Nonveiller, E.

International Symposium on Rock Mechanics, Madrid, 22-24 October 1968, Proceedings, p.389-400. Madrid, Editorial Blume, 1970.
Statistical distribution of joints and fissures in rock permits the seepage problem to be considered as a gravitational potential flow through a homogeneous porous medium (Darcy's Law). Recommends grouting test and split spacing method. Use of models or computers permits the study of the effect of depth and the thickness of the grouted zone on the seepage pattern.

PROPERTIES OF CLAY-CEMENT SUSPENSIONS FOR GROUTING P

Nonveiller, E., and Habekovic, M.

International Congress on Large Dams, 7th, Rome, 1961, Transactions, vol.2, p.593-606.
Useful practical description of laboratory tests on grout samples with comparative data for field tests. Discussion of desirable properties of grout and how to obtain them. Evaluation of the effect of various amounts of cement.

A RATIONAL APPROACH TO DESIGN OF GROUT CURTAINS P

Nonveiller, E.

International Society for Rock Mechanics, Second Congress, Belgrade, 1970, Proceedings, vol.3, theme 6, no.13, p.217-222.
Results of grouting tests carried out by successively splitting the distances between test holes provide a basis for rational design of the grout curtain. Basic equations are presented for assessment of economics of a grout curtain based on flow analysis.

ULTIMATE HORIZONTAL SHEAR STRENGTH OF PRESTRESSED SPLIT BEAMS P

Nosseir, S.B., and Murtha, R.

Port Hueneme, Calif., U.S. Naval Civil Engineering Laboratory, Technical Report no.NCEL-TR-707, January 1971.
This report deals with the horizontal shear resistance and behavior of prestressed concrete composite beams when the interface is selected to pass through the centroid of the composite section. All test beams were posttensioned and grouted and had the same nominal dimensions. Beams with rough interfaces showed an increase in the ultimate horizontal shear strength of about 100 psi over that of duplicate beams with smooth interfaces.

NOTES FROM ACROSS THE SEA C

Coal Age, vol.33, no.2, p.106-107, February 1928.
Patented system known as the Francois Cementation Method has been quite generally adopted in heavily watered ground. It consists of filling the crevices with thin cement grout under pressures as high as 3000 lb per square inch, such grouting being preceded by the injection of two chemicals, silicate of soda and sulphate of alumina, either separately or combined.

SESSION IV: OTHER IMPROVEMENT TECHNIQUES (ADDITIVES, GROUTING, THERMAL, ELECTRO, VIBROFLOTATION, BLASTING, COMPACTION PILES)

Olson, R.E.

Placement and Improvement of Soil to Support Structures, Proceedings of Conference held at Cambridge, Mass., August 26-28, 1968. New York, American Society of Civil Engineers, p.91-92, 1968.
A brief report of the papers is given in Session IV.

PLASTIC GROUTS M

Overbeck, C.F.

Chemical Engineering, vol.73, no.19, p.220-226, September 12, 1966.
Stronger epoxy and polyester grouts have been replacing the traditional sand-cement mixture reducing regrouting costs by means of newer dry-pack and pressure-injection method; method and materials affect grouting time; machinery for preparing plastic grouts; pressure injection grouting method and its advantages; description of epoxy-sand grout, dry-pack epoxy grout, and polyester grout.

ETUDE COMPARATIVE DE QUELQUES COULIS D'INJECTION (COMPARATIVE STUDY OF SOME GROUTS) P

Paillere, A.M.

Bulletin de Liaison des Laboratoires des Ponts et Chaussees, no.52, p.35-47, May 1971.
Studies of a comparative study of all the properties of the twenty-three grouts customarily employed on working sites, a study of the properties of L.C.P.C. grouts under the same experimental conditions and a study of the influence of mixing methods on the essential characteristics of grouts. In French.

POST-TENSIONED TENDONS IN PRE-STRESSED CONCRETE--TO GROUT OR NOT TO GROUT?

Park, R.

New Zealand Engineering, vol.30, no.11, p.315-319, November 1975.
The need to grout post-tensioned tendons in prestressed concrete structures is discussed. The possible alternative of using unbonded tendons is explored. Considerations involve corrosion of tendons, extent of concrete cracking, flexural strength of sections, fatigue of anchorages, energy dissipation and elastic recovery, energy release at failure, friction losses, and other factors.

NON-SHRINK GROUT AND CONCRETE P

Patch, O.G.

American Concrete Institute, Proceedings, vol.35, p.424, April 1939.
Brief discussion of how long grout can be mixed and still be suitable for use.

FORT LOUDOUN DAM

Pauls, A.L.

American Society of Civil Engineers, Proceedings, vol.72, no.10, p.1332-1351, December 1946.
Foundation rock, limestone, marble and shale with solution cavities at unprecendented depths below water table. Established grouting procedures described briefly to permit complete discussion of deep mining operations in large bedding cavities.

KRUSCIA STORAGE BASIN (YUGOSLAVIA) IN THE CAVERNOUS KARST AREA P

Pavlin, B.

International Congress on Large Dams, 10th, Montreal, 1970, Transactions, vol.2, p.209-224.
Studies based on hydrogeological and morphogenetical studies and large investigation work based on these studies concluded that water-tightness of karst storage basin might be economically realized by means of a grout curtain in the cavernous karst area of the damsite.

TESTS ON CHEMICAL GROUTING AND WATERPROOFING BY USING AMINOPLAST RESINS M

Petrasovits, G.

International Conference on Soil Mechanics and Foundation Engineering, Budapest, 1963, (organized by Hungarian Academy of Sciences), Proceedings, p.429-440.
Chemical and physical properties of four aminoplast resins which have been developed for chemical grouting of sand. Laboratory grouting tests on silty sand are reviewed.

GROUTING PILES WHILE DRIVING

Phares, L.J.

Sixth Annual Offshore Technology Conference, Houston, Texas, May 6-8, 1974, Preprints, vol.2, p.505-512.
Raymond International, Inc. has developed a method for simultaneously grouting and driving piles. In the method described in this paper a pile is fitted at the tip with an oversized shoe which provides annular space around the pile as it is driven. This annulus is filled with grout while the pile is being dynamically installed, through a manifold built in the oversized tip. This assures continous grouting of the pile/soil interface, as well as reducing the side friction on the pile during driving.

APPLICATION OF CHEMICAL GROUTS TO GROUND CONSOLIDATION C

Plaisted, A.

Ground Engineering, vol.7, no.4, p.42-44, July 1974.
Discusses the various chemical grouts available. Also discussed are methods of application, including the one-shot method and the two-shot method. Specifically, the Joosten Method is discussed (2-shot calcium chloride and sodium silicate solution). Other silicate grouts, as well as the acrylic polymer type and cyanamide product AM-9 are also discussed.

SELECTION AND USE OF CHEMICAL GROUTS C

Plaisted, A., and Boyes, R.G.H.

Contract Journal, vol.236, p.383-386, 23 July 1970.
This article highlights some of the critical factors to be considered in the selection and injection of a chemical grout. The use of chemical grouts proves particularly effective in (a) bonding cracks, voids, and joints in concrete and rock, (b) increasing the bearing capacity of soils, (c) preventing water penetration through fine fissures and fine-grained soils, and (d) special conditions, such as providing cut-offs against artesian water flow.

COMMENTS ON U.S. GROUTING PRACTICES C, P

Polatty, J.M.

Engineering Foundation Conference, Foundations for Dams, Pacific Grove, Calif., March 17-21, 1974, p.47-55. New York, American Society of Civil Engineers, 1974.
Discussion of current U.S. grouting practice including curtain grouting, water control during construction, area or blanket grouting, compaction grouting, and non-shrink grouts. There is also a discussion of chemical grouts.

GROUTING OPERATIONS FOR UNDERGROUND NUCLEAR TESTS P

Polatty, J.M., and Bendinelli, R.A.

Military Engineer, vol.53, no.356, p.460-462, November - December 1961.
Instrumenting effects of nuclear tests required use of grouts with different setting characteristics; varying proportions of portland cement, aggregate, diatomite, aluminum powder, water, and hydrostone varied strength, setting time, and shear resistance to satisfy requirements of various locations of instruments.

SYMPOSIUM ON GROUTING: INVESTIGATION OF SAND-CEMENT GROUTS P

Polatty, J.M.

American Society of Civil Engineers, Journal of Soil Mechanics and Foundation Division, vol.87, no.SM2, p.83-93, April 1961, Paper 2795.
The purpose of the investigation was to determine the maximum amount of different types and gradations of sand that could be used in a portland-cement grout without injuring its pumpability. In addition, studies were made of the effect of various admixtures on sand pumpability, using sands that either were deficient in, or contained ample amounts of, material passing a no.100 sieve.

BOND STRENGTH CHARACTERISTICS OF GROUTS CONTAINING AN EXPANSIVE COMPONENT P

Polivka, M., and Kline, A.

RILEM (Reunion Internationale des Laboratoires d'Essais et de Recherches sur les Materiaux et les Constructions), Bulletin no.13, new series, p.24-28, December 1961.
Studies were made of bond strength characteristics of grouts containing an expansive constituent. It was found that the use of grout mixtures containing the calcium sulfoaluminate expansive component used in this investigation will produce considerably higher bond strengths than those obtained with conventional grouts.

GROUTS FOR POST-TENSIONED PRESTRESSED CONCRETE MEMBERS P

Polivka, M.

Prestressed Concrete Institute Journal, vol.6, no.2, p.28-38, June 1961.
Discusses grouting techniques, mix proportions of grout, and testing methods for grouts used with post-tensioned concrete members.

PREPLACED AGGREGATE CONCRETE FOR STRUCTURAL AND MASS CONCRETE P

American Concrete Institute Journal, vol.66, no.10, p.785-797, October 1969.
Outlines uses of this method of preplaced aggregate concrete construction. Discusses selection of materials and grout mix proportioning. Recommendations for form preparation, aggregate placing, arrangement of piping, grout pumping, and sequence of injection, finishing, curing and methods of quality control are made. Fundamentals of good practice in preplaced aggregate construction are recommended by which unanticipated problems can be remedied or avoided.

PRINCIPLES OF GROUTING SELECTION M

Civil Engineering & Public Works Review, vol.66, no.783, p.1137, 1142, October 1971.
Discusses the various types of grouting material, mechanics of injection, and methods of stabilizing ground.

NEW TOOLS AND TECHNIQUES FOR DEWATERING P, M

Prugh, B.J.

American Society of Civil Engineers, Journal of the Construction

Division, vol.86, no.CO1, February 1960, Paper 2356.
General review of dewatering methods including a brief discussion of the use of grouting for control of ground water flow.

PARTICLE SEPARATION IN SOILS ENGINEERING M

Raffle, J.F.

Filtration and Separation, vol.3, no.4, p.312-314, July - August 1966.
This paper discusses the physical conditions applying during the injection of a particular grout into alluvial ground and how the presence of particles in the grout will affect the conditions under which the grout can be used.

ENGINEERING USES OF EPOXY GROUTING COMPOSITIONS C

Ranger, .O.

Plastics Institute, Transactions, vol.30, p.93-94, February 1962.
One of the most useful properties of epoxy resins is their excellent adhesion to concrete, wood, and most metals. This, combined with their high compressive strength and good dimensional stability, makes them suitable for grouting or embedding compositions. The grouting compositions are formulated with the epoxy resin and a curing agent or hardener in separate packs which are thoroughly mixed just before application, and the compounds are designed to harden at ambient temperature.

PREDICTION OF SETTLEMENT IN LANDFILLS FOR FOUNDATION DESIGN PURPOSE

Rao, S.K.

Morgantown, W. Va., West Virginia University, Doctoral Thesis, 1974.
This investigation studied experimentally the factors influencing the magnitude and rate of settlement of refuse landfills. Experimental investigations included the study of fly-ash grout strength, the development of techniques for injection grouting of refuse, laboratory tests on grouted and ungrouted refuse specimens, and field studies which included the instrumentation and installation of large-scale grouted and ungrouted refuse test sections.

WHY PAPER MILLS SHOULD USE SPECIALLY FORMULATED GROUTS M

Read, G.W.

TAPPI Engineering Conference Preprint, Toronto, Ont., September 28-October 2, 1975, vol.2, p.121-123. Atlanta, Ga., TAPPI, 1975.

AD-A057 831 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 11/2
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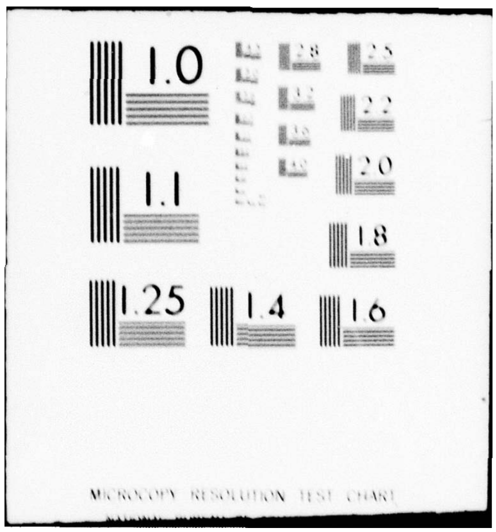
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MICROCOPY RESOLUTION TEST CHART

Special grouts for basing machinery and equipment in paper mills are described. Special qualities of different type grouts are listed, together with recommendations where they are to be used.

SYSTEMATIC APPROACH TO GROUTING M

Reed, J.J.

Mining Congress Journal, vol.48, no.1, p.49-51, 1962.
Procedure for placing grouting work on systematic and quantitative basis; examples of problems encountered in grouting and suggested solutions; factors involved in selecting grouting materials for particular applications.

INVENTIVE DESIGN C, P, M

Reid, N.G.

Consulting Engineer, vol.37, p.55, June 1973.
Discussion of research and development of various types of grouts including Joosten, cement, and fine (ground) pfa used in association with chemicals.

RESEARCH TO RATIONALIZE USE OF CONCRETE, MACADAM CONSTRUCTION, STUDY OF GROUT FLOW

Engineering News-Record, vol.112, no.7, p.231-234, February 15, 1934.
A freely flowing grout was found necessary for satisfactory penetration. A "flow core" was devised fashioned after an ordinary funnel. Index of fluidity was taken as proportional to time of emptying in seconds.

ENGINEERING GEOLOGICAL EVALUATION OF RESULTS OF INJECTION BY MEANS OF ISOLINE MAPS MADE IN AUTOMATIC PROGRAM-CONTROLLED DRAWING DEVICES P

Reuter, F., and Dorfer, H.

Wasserwirtschaft-Wassertechnik, vol.21, no.6, p.194-196, 1971.
Isoline maps of permeability of subsoil were designed based on results of grouting work. Gives advice on interpreting faults in rocks, the size of cracks, and their frequency determination. Before and after results are compared.

GROUTING WATER CHANNELS UNDERGROUND P

Rickard, T.A.

Engineering and Mining Journal, vol.114, p.286, August 12, 1922.

EUROPEAN VS. U.S. GROUTING PRACTICES P

Rigny, P.

Engineering Foundation Conference, Foundations for Dams, Pacific Grove, Calif., March 17-21, 1974, p.37-45. New York, N.Y., American Society of Civil Engineers, 1974.
The differences in grouting practices, including both rock grouting and alluvial grouting are discussed.

THE EFFECT OF FROST ON THE GROUT OF PRESTRESSING TENDONS P

Rohnisch, A.

Beton-und Stahlbetonbau, vol.50, p.64-71, 89-93, 1955. (Translation into English available from National Translations Center, John Crerar Library, Chicago, Ill., no.61-20023.)
The tests which have been carried out showed that damage occurring in prestressed concrete structures after periods of frost was attributable to the effect of frost on the grout of the tendons. Methods of ascertaining the frost resistance are proposed for the purpose of approval tests.

ESSAIS DE COMPRESSION RADIALE EN GALERIE (RADIAL TEST IN PRESSURE GALLERY) P

Roman, J., Coll, M., Saracho, J.S., and Peironcely, J.M.

International Society for Rock Mechanics, 2nd Congress, Belgrade, 1970, Proceedings, vol.2, Theme 4, no.12, p.469-474.
A brief outline is given of the tests effected in the pressure gallery of the El Atazar (Madrid) Hydraulic Development which crosses Silurian shale land. A study was made of the improvements introduced by the consolidation of the rock affected by the gallery excavation, through cement grout injection. In French with brief English summary.

ROTARY MIXED-IN-PLACE GROUTING FOUND FEASIBLE P

Civil Engineering, vol.23, no.2, p.74, February 1953.
Discusses a process known as rotary mixed-in-place grouting which offers many satisfactory applications in the solution of difficult foundation stabilization problems. The most significant conclusion of this investigation was that in-place mixing is entirely feasible under field conditions. The load-carrying ability of mixed-in-place soil-cement elements was shown, as well as the high unit compressive strengths obtainable from mixtures of soil and grout. The use of overlapping elements for in-place construction of core walls was also demonstrated.

THE IMPORTANCE OF GROUT PROPERTIES IN GROUTING JOINTED ROCK MASSES P

Ruiz, M.D., and Leone, P.C.

International Association of Engineering Geology, International Congress, Paris, September 1970, Proceedings, p.616-625.
Discusses theoretical grout penetration in plane and smooth fissures in relation to grout rheological constants based on laboratory tests performed with cement of different grain size and mixtures with artificial pozzolan and clay. Complete laboratory study was carried out to design treatment of bedrock at Ilha Solteira Dam in Brazil.

BOND ALLOWANCE FOR GROUTED PRESTRESSED STEEL P

Rush, P.J.

Port Hueneme, Calif., U.S. Naval Civil Engineering Laboratory, Technical Note, NCEL-TN-338, April 1958.
A limited number of grout mixes and grout-placing methods commonly used to provide bond between post-tensioned prestressing wires or bars and concrete structural elements were evaluated according to the primary criterion of bond-strength as measured by pull-out tests; and according to additional criteria such as ease of placing, availability, and cost. The use of at least 40 psi pressure in the grouting cavity was found to be an important factor in the development of bond-strength. It was found that grout should be placed with a positive-action pump.

DETERMINATION IN SITU OF THE STATE OF THE FRERA DAM FOUNDATION ROCK BY THE SONIC METHOD, ITS IMPROVEMENT BY CONSOLIDATION GROUTING AND VERIFICATION OF THE RESULT BY AGAIN USING THE SONIC METHOD P

Scalabrini, M., Carugo, G., and Carati, L.

International Congress on Large Dams, 8th, Edinburgh, 1964, Transactions, vol.1, p.585-600.
Describes detailed methods which were used at the Frera Dam in Italy to determine the elastic modulus of foundation rock by the sonic method. A program of grouting the rock zone by zone was developed and carried out based on this elastic modulus.

LES PAROIS MOULEES DANS LE SOL M

Schneebeli, G.

Paris, Editions Eyrolles, 1971. 191p.
Description of methods of excavation, making joints and placing

the concrete for slurry trenches. Underground work, urbanization, and foundation engineering are examples of the use of slurry trenches. Calculation of concrete reinforcement and of soil pressure, plastic analysis, elastic and anchor calculations, effect of cohesion, special cases and the influence of groundwater are other topics.

DAS VERFESTIGEN ZUM AUSLAUFEN NEIGENDER KOHLE DURCH EINPRESSEN VON KUNSTHARZ

Schuermann, F., and Lappe, F.J.

Glueckhauf, vol.5, p.275-280, January 1962.

UNTERSUCHUNGEN UEBER DIE DURCHLAESSIGKEIT VON RINGRAUMZEMENTATIONEN (INVESTIGATION OF PERMEABILITY OF CEMENT IN ANNULAR SPACE) P

Schwarz, H.

Bergbauwissenschaften, vol.10, no.11-12, p.268-278, June 15, 1963.
Investigation of permeability of grouting cement and pure cement reveal density of grouting cement is strongly influenced by condition of surrounding surface, temperature in borehole and length of fissure; by addition of bentonite or quartz powder, consequences of unsatisfactory density control can be restricted.

GUIDE SPECIFICATION FOR CHEMICAL GROUTS C

Seaman, W.K.

American Society of Civil Engineers, Journal of Soil Mechanics and Foundation Engineering, vol.94, no.SM2, p.345-352, March 1968, Paper 5830.
These specifications make it possible for the specifying engineer to obtain the chemical or chemicals desired and to effect grouting operations of these materials. For the purpose of these specifications, grouts are considered to be any material which may be pumped or placed into the voids in a formation to change the formation properties.

CONSTRUCTION OF THE POWER DEVELOPMENT AT MASSON, QUEBEC P

Serson, H.V.

Canadian Engineer, vol.66, p.4-5, March 13, 1934.

DEVELOPMENT OF LARGE DIAMETER CORE BARREL C

Shackelford, T.J.

Livermore, Calif., Explosive Excavation Research Laboratory, Technical Memorandum no.71-18, 1972.

A test program was conducted to determine the feasibility of using a large diameter core barrel (48-inch) to recover undisturbed samples of crater rubble for physical properties testing. Because of the unconsolidated nature of crater rubble, it is necessary to grout the material before coring. A grout evaluation program was conducted and the resin grout, Cyanoloc, was found to be the most acceptable. Grout disintegration tests were successful on small diameter cores, however, grout disintegration was unsuccessful on a 48-inch core specimen as the heat dissipated too rapidly and was not uniformly applied. Failure to disintegrate the grout from the large diameter specimen terminated the test program.

SHELLPERM PROCESS M

Oil and Gas Journal, February 3, 1949.

Illustration of Shellperm Process of grouting using an emulsion of asphalt in water.

GROUT HOLE ORIENTATION-MATHEMATICAL SOLUTION M

Singhota, J.S.

American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division, vol.95, no.SM4, p.995-1006, July 1969, Paper 6660.

Presents--for use in planning of grouting program--a mathematical solution of problem or orienting grout holes in optimum direction with respect to formation strike and dip for grouting rock formation.

EPOXY RESINS M

Skeist, I.

New York, N.Y., Reinhold Publishing Corporation, 1958.

This monograph discusses the various chemical and physical properties of epoxy resins, which are sometimes used in special grouting applications.

ESTIMATION OF FRACTURE POROSITY IN CRYSTALLINE ROCK C

Snow, D.T., and Karol, R.H.

Princeton, N.J., American Cyanamid Co., Chemical Grouting Topics no.5, 1965.

To determine the groutable porosity of fissured or fractured rock masses, extensive field testing programs may be required. This report outlines a method for testing intrusive or metamorphic rocks.

SOIL CEMENT LABORATORY HANDBOOK P

Chicago, Ill., Portland Cement Association, 1956. 4th ed.

SOME FRENCH METHODS AND MACHINES FOR GROUTING P

Engineering Record, p.495-496, October 30, 1909.
Grout of 2:1 sand and cement was found economical if sand was suitable. Air pressure was found better than pump pressure since the grout injures the piston rapidly.

SOME NOTES ON GROUTING C

Federation Internationale de la Precontrainte Congress, 4th, Rome, 1962, Proceedings, (edited by R.P. Andrew, Cement and Concrete Association, London), Theme 2, Paper 14, p.111-117.
Measurement of fluidity, different grouting tests on site and grouting in winter with methylated alcohol reported from investigations made during the last six years by the Dutch Committee on Grouting. No difference was found when using expanding agent in whether the duct was closed or left open after grouting.

USE OF CEMENT UNDER PRESSURE AS AN AID TO EXCAVATION P

Springer, J.F.

Concrete, vol.118, October 1916.

GROUT SHRINKAGE TESTS P

Stadtfeld, N.T.F.

The Delaware Water Supply News, no.97, p.441, August 1, 1942.
Gives results of shrinkage of grout when poured into a sealed container using various w/c ratios and some sand. Does not apply to grouting where vent is provided for escape of excess water.

BIBLIOGRAPHY OF PRESSURE GROUTING, 1891-1950

Stenger, Ferdinand, Comp.

Denver, Colo., U.S. Bureau of Reclamation, Technical Bibliography no.214, 1951.

WATER-SHUTOFF TECHNIQUES IN AIR OR GAS DRILLING

Sufall, C.K.

American Petroleum Institute (API), Drilling and Production Practice, p.74-77, 1960.
Describes several types of water-shutoff materials and techniques used in drilling.

PATCHING AND GROUTING MATERIALS FOR PORTLAND CEMENT CONCRETE M

Sundquist, C.R.

Sacramento, Calif., California Department of Highways, Report No.CA-HWY-MR635148(7)-72-06, 1972, final report.
This report covers work done on evaluation of 19 commercial products sold as portland cement concrete patching compounds compared with Type III cement mortar. The properties tested included set time, expansion, percent chlorides, percent sulfate, drying shrinkage, abrasion resistance, and compressive strength.

LES INJECTIONS DE COULIS DE CIMENT A L'AIR COMPRIME

Suquet, M.

Annales des Ponts et Chaussees, vol.40, p.37, 1909.

USE OF EPOXY COMPONENTS FOR CRACK-SEALING UNDER PRESSURE M

Tandon, M.

Indian Concrete Journal, vol.42, p.302-313, August 1968.
The paper describes the method of sealing cracks in concrete structures by injecting epoxy compounds under pressure. An introduction to epoxy compounds indicating their uses in the building industry and their properties, and the handling precautions to be observed during operations at site are also discussed.

CONTROL OF GROUTING CURTAINS BY GEOPHYSICAL MEASUREMENTS P

Tkany, Z., and Valtr, V.

Vodni Hospodarstvi, vol.21, no.12, p.334-340, 1971.
Discusses water pressure tests which are the most common of the control methods used in testing the efficiency of a grouting curtain. Describes geophysical methods suitable for the control of grouting works. Survey of the use of these methods.

BARRAGES DE L'OUED, FODDA ET DU PONT GHRIB. LES TRAVAUX D'EXTENSION DU PONT D'ALGER

Truffet, M.

Annales des Ponts et Chaussees, vol.1, p.41, 1831.

REPORT OF LABORATORY PILOT STUDIES FOR ROCK BONDING WITH CHEMICAL GROUTS C

U.S. Army Engineer Division, Ohio River

Cincinnati, Ohio, U.S. Army Engineer Division, Ohio River, Division Laboratories, Technical Report no.2-31, June 1963.
The purpose of these studies by F.M. Mellinger was to develop information for the consideration of the use of a special epoxy resin system as a chemical grout for rock-bonding at the NORAD Project. The studies disclosed that the specific epoxy resin system had more suitable characteristics for the usage considered than the polyester resin system.

ADMIXTURES FOR CONCRETE P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-727, June 1965.
The report classifies admixtures in 15 categories: accelerators, water reducers, and set controllers; grouting, air-entraining admixtures, etc. This report was prepared by Bryant Mather.

BENTONITE GROUT TESTS

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., The Experiment Station Bulletin (Soil Mechanics), no.12, p.6-7, September 1, 1939.
Condensation of report on study of stability of slag treated with bentonite grout made by the Pittsburgh Engineer District, CE.

DETERMINATION OF THE HUGONIOT EQUATION OF STATE OF GROUT: REPORT 1, 1963 TESTS C, P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Report no.6-669, January 1965.

The emplacement of instruments in the hydrodynamic shock range of a nuclear detonation has necessitated the study of the shock characteristics of the emplacing grouts. If the Hugoniot equation of state of the grout does not match that of the surrounding medium, a mismatch will occur at the interface of the grout and surrounding medium, causing a distortion of the shock front. The Hugoniot equation of state is determined by the locus of pressure-volume joints generated by shocks from a given state. In this investigation, plane wave lenses were employed to produce plane shocks in the range of 100 to 300 kilobars in the grout specimens. The first grouts tested were hydrating cement grouts, using portland or calcium-aluminate cement; they were intended to match the shock impedance of rock salt. Because of what appeared to be a low shock impedance of the hydrating cements, an epoxy-resin grout was proportioned. Two pressure-volume points were determined for this grout which showed this mixture to have a higher impedance than rock salt. Therefore, a match could be achieved by replacing some of the aggregate with a material having a lower shock impedance. This approach may offer a means of achieving shock-impedance matches of grouts with natural materials. This report was prepared by Howard Sugiuchi.

DETERMINATION OF THE HUGONIOT EQUATION OF STATE OF GROUT: REPORT 2, 1964 TESTS C, P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Report no.6-669, August 1967.

The development of transducers for measurement in the high pressure region during conventional and nuclear explosions has necessitated the investigations of the shock characteristics of the grouts which are used to couple the transducers to the media, and, in addition, requires the development of grouts to match the behavior of the media, such as granite and rock salt. The use of a Hugoniot synthesis provided a guide post for the development of grouts which, over a limited pressure range, match the shock characteristics of rock salt, basalt, and granite. This report was prepared by Howard Sugiuchi and B.R. Sullivan.

DEVELOPMENT OF A MICROCRACKING TECHNIQUE FOR MEASURING IN-SITU STRESS AND STRAIN; REPORT 2: FIELD TESTS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Report no.6-764, Report 2, March 1967.

A laboratory study of the relation between the magnitude of static and dynamic stresses to which hardened portland cement grout specimens were subjected and the degree of resulting internal microcracking

in the specimens had indicated that this relation might permit use of grout cylinders as mechanical type strain gages for measuring free-field strain in insitu material. This report was prepared by R.L. Stowe.

EFFECTS OF WATER ON EPOXY-RESIN SYSTEMS C

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Report C-71-2, September 1971.
In this study by T.B. Husbands, C.F. Derrington, and L. Pepper, the effect of continuous immersion in water on the tensile strength, tensile elongation, tensile modulus, flexural strength, flexural strain, and bond strength of five different epoxy-resin systems was evaluated. The water absorption of the five systems was also obtained. One of the systems will meet Federal requirements for epoxy resins and another contains the same system but includes sand as a filler. All of the physical properties of these two systems were deleteriously affected by storage in water, and, therefore, the systems should not be used when the cured systems will be subjected to immersion in water for periods longer than one month. In addition, every effort must be made to protect these two systems from undue exposure to water. The test results also indicate that the use of a modifier in proper amounts will produce a large increase in strength and elongation and a large decrease in tensile modulus and water absorption. Two of the modifiers tested, polymide and amidopolyamine, produced epoxy-resin systems which were not deleteriously affected by immersion. The addition of sand in the proper proportions will materially reduce all the physical properties of the resin system except bond strength, but will increase significantly the modulus of elasticity. The testing errors determined in this investigation are given as a guide for testing the engineering properties of epoxy-resin formulations.

EQUATION OF STATE STUDIES OF EIGHT ROCK TYPES AND ONE ROCK-MATCHING EPOXY GROUT M

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no. C-69-14, September 1969.
Shock equation of state studies have been conducted on rock from four locations in the United States: Washington, Wyoming, New Mexico, and Colorado. Equation of state data were obtained on the following rock types: basalt, soda diorite, granite, gneiss, limestone, sandstone, shale, and tonalite. One rock-matching epoxy grout was also fabricated and tested at low pressures. This paper was prepared by D.L. Ainsworth and B.R. Sullivan.

GROUTING OF FOUNDATION SANDS AND GRAVELS; APPENDIX A: TESTS OF ACRYLAMIDE N, N' METHYLENE-BIS-ACRYLAMIDE AS A GROUTING AGENT C

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Memorandum no.3-408, Appendix A, January 1956.

Tests were undertaken to further explore the possibility of using certain chemicals of the acrylate group which had promise as soil grouting agents. The principal purpose of the laboratory tests was to determine the finest grain size and maximum density of sand that could be grouted successfully using acrylamide. Other variables investigated in the tests were strength of the acrylamide solution, strength of the redox agent, injection pressure, and size of sample. Sixteen tests were conducted to study the effects of all the variables. A series of small-scale tests were made in beakers to determine the most satisfactory concentration of acrylamide and redox agent to use. After completion of the grout injection, a second permeability test was performed to determine the effectiveness of the grouting operation. This report was prepared by J.E. Mitchell.

INFLUENCE OF BACKFILL PROPERTIES ON THE COLLAPSE OF PIPES UNDER DYNAMIC LOADS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Report no.N-73-5, July 1973.

Important to the succesful stemming and containment of underground nuclear explosions is the ability of ground shock pressures generated by an explosion to collapse the Line-of-Sight (LOS) pipe for a significant distance from the zero point. Dynamic tests were conducted on a copper tube imbedded in grouts of various physical properties and explosively loaded by a traveling detonation wave. The grouts were chosen to be representative of those used at the Nevada Test Site and to provide a significant range of strength and density. A theoretical analysis of a typical test cross section was made assuming the tubing and the grouts to behave as rigid plastic materials and the traveling load to be stationary. This report was prepared by J.L. Drake and C.E. Joachim.

INSTRUMENTS FOR DETERMINING THE ELEVATION OF GROUT IN DEEP HOLES; REPORT I P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-650, May 1964.

The need to know the elevation of grout used to seat shock-sensitive instruments in deep holes in connection with underground nuclear testing was responsible for the investigation of devices for determining grout elevation. Four devices were developed and tested in the laboratory and three in deep holes in connection with Project DRIBBLE at Hattiesburg, Mississippi, and Project CLEARWATER at the Nevada Test Site, Mercury, Nevada. Further work to improve the pressure switch, differential detectors, and the resistivity method is recommended. This paper was written by B.J. Houston.

INSTRUMENTS FOR DETERMINING THE ELEVATION OF GROUT IN DEEP HOLES; REPORT 2: FURTHER INVESTIGATIONS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper 6-650, April 1966.
In this investigation by B.J. Houston, a special grout designed to match the strength, density, and sonic characteristics of the surrounding medium is required for seating shock-sensitive instrumenttation in drilled holes in connection with underground nuclear tests. To ascertain that grout has actually surrounded the instruments, three methods of detecting the arrival of grout at any predetermined elevation in a hole were developed. Two of the methods utilize the difference in density between the drilling mud or water initially in the hole and the displacing grout. The third method utilizes a metallic-seeded mud that is pumped downhole immediately ahead of the grout, is therefore displaced uphole, and is attracted by two magnetized electrodes upon reaching them, thereby bridging the gap and reducing the resistance between the electrodes. As a result of the investigation, use of the pressure switch is recommended. Should pressure switches not be available, the transformer densimeter can be used if there is a minimum difference in density of 25 pcf. No further work to develop the resistivity method is recommended.

INVESTIGATION OF A METHOD TO DETERMINE HEIGHT OF GROUT IN A DEEP HOLE P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-517, August 1962.
An investigation was conducted in the laboratory at the Waterways Experiment Station and in the field at the U.S. Atomic Energy Commission's Nevada Test Site to determine whether any of several commercially available instruments could distinguish between drilling mud, or water, and grout in deep holes. Two types of geophones and a pressure-sensitive vibration detector were tested in the laboratory. One of the geophones and the vibration detector tested in the laboratory phase, and also a temperature-sensitive thermistor and two conductivity instruments were tested in the field. It is recommended

that a pH meter, a hydrogen detector, a differential pressure pickup, and a more sensitive bridge for measuring conductivity be investigated to determine their capabilities for indicating height of grout in a deep hole. This report was prepared by B.J. Houston.

INVESTIGATION OF A PROPRIETARY CHEMICAL AGENT FOR SOIL STABILIZATION C

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper S-70-11, April 1970.

Field and laboratory investigations were conducted by G.R. Kozan and J.O. Stouffer on a proprietary material to determine its potential for use as a soil stabilizer for military purposes and its effectiveness in pretreating soil to improve penetration of dust-control materials, e.g. Asphaltic Penetrative Soil Binder (APSB). Two test sections, one untreated and one treated with Product A, were constructed in an open area and trafficked with a military vehicle and a test load cart. Measurements and observations made during construction and traffic testing showed no significant difference between the treated and untreated sections with respect to strength and ability to support traffic under either wet or dry conditions. For the penetration tests, an open area was bladed to remove all vegetation. Half of this bladed area was pretreated with Product A, and then APSB was applied; the other half of the area received only an application of the APSB. Test results indicated that the depth of penetration of the APSB was not affected appreciably by pretreatment of the soil surface with Product A. Laboratory tests on representative soil samples obtained from the field test sections indicated no significant alteration of water content or Atterberg limits and only a minor decrease in pH values for treated areas. It was concluded that Product A has no potential for military soil stabilization purposes, and it is recommended that no further tests of this material be conducted.

INVESTIGATION OF EXPANDING GROUT AND CONCRETE; REPORT 1: PRELIMINARY STUDIES P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Report C-70-2, May 1970.

Portland cement and grout are construction materials used in widely varied types of structures. One of the major disadvantages of these materials is drying shrinkage. Researchers have worked on this problem for many years, and technology has advanced to the point where products are now being manufactured which, when used in portland-cement concrete, can cause expansion to counteract shrinkage or, depending on amounts used, cause positive expansion. Two expansive mixtures were investigated in the program described herein: Type K expansive cement, which consists of portland cement clinker, anhydrous calcium aluminate sulfate, lime and calcium sulfate; and

Type M expansive cement, which is a mixture of portland cement, calcium aluminate cement, and calcium sulfate. The purpose of the research effort was to develop expansive concrete and grout mixtures for use in structures in connection with underground nuclear testing. This report was prepared by B.J. Houston.

INVESTIGATION OF EXPANDING GROUT AND CONCRETE; REPORT 1: SUMMARY OF FIELD MIXTURE TEST RESULTS, JULY 1969 THROUGH JUNE 1970 P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.C-71-5, June 1971.
Laboratory evaluations were made of fourteen grout mixtures and seven concrete mixtures, all of which contained Type K expansive cement wholly or in part. The mixtures varied widely in ingredients, proportions, curing, and the type of evaluations made. Very few direct comparisons of behavior among mixtures could be made. Three special control study mixtures were also evaluated as a pilot study. Each mixture was evaluated for some, but not all, of the following physical characteristics: expansion, strength, modulus of elasticity, compressional wave velocity, constrained pressure, efflux time, temperature rise and slump loss. Comparisons were made as appropriate. This report was prepared by G.C. Hoff.

INVESTIGATION OF EXPANDING GROUT AND CONCRETE; REPORT 2: SUMMARY OF FIELD MIXTURE TEST RESULTS, JULY 1970 THROUGH JUNE 1971 P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.C-71-5, Report 2, January 1973.
Evaluations were made of twelve grout mixtures, six groutcrete mixtures, and eleven concrete mixtures, all of which contained Type K expansive cement wholly or in part. The mixtures varied widely in ingredients, proportions, curing, and the type of evaluations made. Very few direct comparisons of behavior could be made. Three self-stressing Type K expansive cements were used. Two of the cements were formulated to be moderately expansive while the other was to be highly expansive. The highly expansive cement was used as a portion of the total cement in a mixture. The moderately expansive cements were used as either the only cement in the mixture or as a portion of the total cement. Each mixture was evaluated for some, but not all, of the following physical characteristics: expansion, strength, modulus of elasticity, compressional wave velocity, temperature development, slump loss, and efflux time. This report was prepared by G.C. Hoff.

INVESTIGATION OF GAGE-PLACEMENT EFFECTS ON A STRESS GAGE EMBEDDED IN GROUT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no. S-73-37, June 1973.
The report documents a study conducted on the Gulf Radiation Technology (GRT) piezoelectric stress gage in support of the Diamond Mine Event at the Nevada Test Site (NTS). The gage was first calibrated in oil and then embedded in an NTS grout and tested under conditions of uniaxial stress. The results of these tests indicated a slightly nonlinear output of the gage under hydrostatic loadings and an underregistration of the gage when embedded in the grout. This report was prepared by J.Q. Ehrgott.

INVESTIGATION OF PROCEDURES FOR TESTING GROUT FLUIDIFIERS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-720, April 1965.
This study of methods of testing grout fluidifiers by R.L. Curry is one phase of an investigation of the resistance of preplaced aggregate concrete containing fly ash to freezing and thawing. The tests described herein were performed to establish suitable apparatus and procedures for use in selecting satisfactory fluidifiers for the later phases of the investigation. In this phase it was desired to test the grout characteristics in such a way that the results would reflect the character of the grouts to be pumped in later phases. Therefore, it was considered desirable to vary the test methods as necessary to best measure the properties to be evaluated. The specific problems studied in, and objective of, this phase of the investigation were as follows: (a) To determine the time of efflux requirements for the grouts, (b) to study the amount of water extraction which would be expected in the grouts and determine water retentivity of comparable grouts, (c) to determine suitable percentage of expansion of grouts at standard times after addition of fluidifier, (d) to establish suitable time-of-setting requirements for the pumpable grouts, (e) to develop a good simple strength test, preferably of 2-inch cubes, for determining proper strength of the pumpable grouts, and (f) to determine what type of laboratory mixer would mix grouts in small batches having properties most similar to those of batches mixed in large grout mixers.

INVESTIGATION OF SAND-CEMENT GROUTS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no. 6-410, September 1960.
The purpose of this investigation by J.M. Polatty, in general, was to determine the maximum amount of sand that could be used in a

portland-cement grout without injuring its pumpability. In order to widen the scope of the investigation, different gradations and types of sands were test-pumped. In addition, the effect of various admixtures on sand pumpability, using sands that either were deficient in, or contained ample amounts of, materials passing the no.100 sieve, was studied. A number of conclusions can be drawn from the data obtained in this investigation, among which are: (a) sand deficient in material passing the no.100 sieve can be successfully pumped in grout mixtures without the use of an admixture, (b) concrete sands can be used in portland-cement grout mixtures provided they are scalped over the no.16 sieve, (c) an increase in fine material in the quantity of sand found pumpable, (d) manufactured sands can be successfully pumped in portland-cement and grout mixtures, (e) the specific gravity of the sands included in this test program has little or no effect on the pumping characteristics of the grout, (f) in using sand deficient in minus no.100 sieve size material, the addition of a finely divided mineral admixture increases the sand-carrying capacity of the grout; and (g) the addition of a finely divided mineral admixture to a normal portland cement-sand grout will increase its sand-carrying ability.

AN INVESTIGATION OF SANDED GROUTS USING MANUFACTURED SANDS P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no. 6-195, January 1957.
In this study by J.M. Polatty, comprehensive investigation of grouts containing both natural and manufactured sands was conducted by the Concrete Division of the Waterways Experiment Station. In the study of manufactured sand grouts an investigation was made of physical characteristics, ease of pumping, and the effects of adding certain mineral fines. Results were compared with test results for natural sand grouts. The investigation consisted of pumping tests to determine whether or not a selected combination of materials could be pumped. Tests were made with the same combinations to determine time of setting, amount of bleeding, and compressive strength of the grout mixtures. After the pumping tests were completed, the initial and final time of setting, the percent bleeding, and the compressive strengths of the cubes at seven and twenty-eight days were obtained.

INVESTIGATION OF SHRINKAGE-RESISTANT GROUT MIXTURES P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Report no.607, August 1962.
The investigation was divided into four phases. The first phase was a review of literature covering (a) theories concerning shrinkage, (b) methods and materials used to obtain shrinkage resistance in grouts, and (c) methods for determining volume change of grouts. The second phase consisted of studies of the use of metallic aluminum powders at various setting temperatures as expansion agents in Type A grouts. This phase also included study of six methods of measuring

the volume change of grouts. The third phase was a study of the behavior of two Type M and one Type A grouts when used for grouting a simulated machine-base bedplate. Compressive, flexural, and bond strengths of these grouts were also determined. The fourth phase consisted of laboratory studies of two types of grout mixtures; the shrinkage-resistant properties of one type (A) are derived from the presence of readily oxidized metals. This report was prepared by R.A. Bendinelli.

INVESTIGATION OF THE RESISTANCE OF FRESHLY INJECTED GROUT TO EROSION AND DILUTION BY FLOWING WATER P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no. C-76-4, June 1976.
The relative resistance of 35 grout formulations to the effects of erosion and dilution by flowing water with a velocity of 0.3 fps or more was determined by a series of height-of-grout measurements conducted at fixed intervals along the transparent side of a flow channel model. Grout retention in the channel was determined immediately after injection in the flowing water and after 1 or 2 hours of additional water flow. Grouts that were more resistant to the effects of flowing water than other grouts tested are identified, and the materials and physical properties contributing to their increased resistance are discussed. This paper was prepared by D.M. Walley.

METHOD OF SELECTING PROPORTIONS FOR INTRUSION GROUT MIXTURES

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Handbook for Concrete and Cement, CRD-C 85-64, 1 December 1964.

METHOD OF TEST FOR EXPANSION OF GROUT MIXTURES

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Handbook for Concrete and Cement, CRD-C 81-74, Revised 1 June 1974.

METHOD OF TEST FOR FLOW OF GROUT MIXTURES (FLOW-CONE METHOD)

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Handbook for Concrete and Cement, CRD-C 79-58, 1 September 1958.

METHOD OF TEST FOR TIME OF SETTING OF GROUT MIXTURES

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Handbook for Concrete and Cement, CRD-C 82-76, 1 December 1976.

METHOD OF TEST FOR WATER RETENTIVITY OF GROUT MIXTURES

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Handbook for Concrete and Cement, CRD-C 80-64, 1 December 1964.

PROJECT SHOAL: PROJECT OFFICERS REPORT - PROJECT 9.1; LABORATORY AND FIELD GROUTING SUPPORT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no. 6-700, VUF-2700, May 1965.
In Project Shoal, a low-yield nuclear device was to be detonated underground in granodiorite at a site approximately 28 miles southeast of Fallon, Nevada, October 26, 1963. The U.S. Army Engineer Waterways Experiment Station determined pertinent physical properties of the granodiorite and developed a grout mixture with similar properties for use in embedding instruments to measure earth motion, particle motion, etc. Two other mixtures were developed to meet less rigid requirements. In all, WES grouted 10 surface stations, 4 surface and 30 tunnel instrument holes, 5 instrument niches, and 1 exploratory hole. The compressive strength and ultrasonic pulse velocity of the specimens of the grout intended to match the granodiorite, though considerably greater than those of conventional grouts, were something less than desired. This report was prepared by J.M. Polatty and J.E. McDonald.

RESEARCH IN FOUNDATION GROUTING WITH CEMENT P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no. 6-384, March 1960.
Results of the laboratory and field tests described in this paper show the advantages and disadvantages of cement grout incorporating admixtures, of varying water-cement ratios and of varying grading and fineness of grout ingredients. In addition, grouting techniques, grouting pressures, and types of equipment utilized in these tests are described. This paper was prepared by T.B. Kennedy.

SONISCOPE INVESTIGATION OF ELMENDORF AFB HOSPITAL, ANCHORAGE, ALASKA — M

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no. 6-761, December 1965.
The hospital building at Elmendorf AFB, Anchorage, Alaska, was one of the many structures damaged by the earthquake which occurred on 27 March 1964. The U.S. Army Engineer Waterways Experiment Station furnished a soniscope and crew to make velocity measurements on concrete of suspected inferior quality in the hospital to locate any concrete damaged by cracking or shattering that might not be evident from a visual inspection and to obtain an indication of the success of repair by epoxy grouting. This report was prepared by H.T. Thornton.

SPECIFICATIONS FOR GROUT FLUIDIFIER

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Handbook for Concrete and Cement, CRD-C 566-64, 1 December 1964.

STUDY OF MICROCRACKING OF HARDENED PORTLAND-CEMENT GROUTS INDUCED BY DYNAMIC LOADING — P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Miscellaneous Paper no.6-731, August 1965.
This study by L.E. Fouche investigated the effect on the degree of microcracking of hardened portland cement grout specimens of the application of dynamic loads of various magnitudes. It was found that the filtered particle method produced the best results of the methods tested for crack detection. It was also learned (from the specimens subjected to no load) that care must be taken to avoid excessive initial cracking of the specimens from shrinkage.

USE OF SELF-STRESSING EXPANSIVE CEMENTS IN LARGE SECTIONS OF GROUT, MORTAR AND CONCRETE. REPORT 1: PUMPABLE MORTAR STUDIES — P

U.S. Army Engineer Waterways Experiment Station

Vicksburg, Miss., Technical Report no. C-74-6-1, August 1974.
In order to understand the behavior of large sections made with a grout, mortar, or concrete containing expansive cement, a three-phased laboratory program was initiated, the last phase of which is to study grout. This report was prepared by G.C. Hoff.

THE EFFECTS OF WATER AND CEMENT GROUT ON THE SHEAR STRENGTH OF NATURAL AND ARTIFICIAL JOINTS IN GRAND COULEE GRANITE P

U.S. Bureau of Reclamation

Denver, Colo., U.S. Bureau of Reclamation, Engineering and Research Center, REC-ERC-71-16, 1971. Prepared under contract at University of Illinois, Dept. of Civil Engineering, by J.H. Coulson, and D.U. Deere.

To evaluate the effects of water and portland cement grout on the typical rock joints, direct shear strength tests were performed on NX-size granite cores from the site of the Third Powerplant, Grand Coulee Dam, Wash. Direct shear and sliding resistance data were obtained on: (a) natural rock joints, (b) grouted natural joints, (c) artificial joints, and (d) diamond-sawed granite surfaces. The variables considered for grouted joints include grout thickness, surface topography of the joint, and the mode of failure of the grout. Results indicate that water reduces joint sliding resistance (residual shear) 6 to 14% and that grouting significantly lowers the joint shear strength.

INSTALLATION, PRESSURIZATION AND GROUTING OF HYDRAULIC FLAT JACKS IN MORROW POINT POWERPLANT

U.S. Bureau of Reclamation

Denver, Colo., U.S. Bureau of Reclamation, Concrete and Structural Branch, REC-OCE-70-19, 1970.

Report prepared by M.L. Haverland.

GROUTING METHODS AND EQUIPMENT P

U.S. Dept. of the Army

Washington, D.C., Technical Manual no.5-818-6 (Air Force Manual No.88-32), 1970.

This manual was prepared to provide guidance in the use of pressure grouting as a means of correcting existing or anticipated subsurface problems. Information on procedures, materials and equipment for use in planning and executing a grouting project is included, and types of problems that might be solved by pressure grouting are discussed. Methods of pressure grouting that have proven to be effective are described, and various types of grouts and their properties are listed.

THE USE OF CEMENT GROUT UNDER PRESSURE AS AN AID TO EXCAVATION P

Concrete, vol.9, p.118, October 1915.

Equipment not expensive. Description of repairs to various structures. Sand cannot be grouted thoroughly.

SOME PROBLEMS OF THE ARTIFICIAL STRENGTHENING OF ROCKS FOR CONSTRUCTION PURPOSES C

Voronkevich, S.D.

Vestnik Moskovskogo Universiteta Geologiya (Moscow University Geology Bulletin) vol.29, no.1, p.57-69, 1974.
The injection process as used for artificially strengthening of rock by chemical cementation.

GROUTING TECHNIQUES C, P

Walker, J.

Plant Engineer, vol.11, no.5, p.321-325, May 1967.
Grout may consist of cement, chemical, limestone dust, cement and sand, or fly ash. Machinery includes drills of various sizes, jack-hammers and specially constructed reciprocating or rotary cement pumps. Case histories of arresting foundation settlement, controlling mine fires, sealing leakage and restoring masonry. Description of guniting process.

DE QUELQUES FACTEURS INFLUENCANT LES PROPRIETES DES COULIS TERNAIRES D'INJECTION CIMENT-ARGILE-EAU (FACTORS INFLUENCING THE PROPERTIES OF CLAY-CEMENT GROUT) P, M

Wallays, M.

International Conference on Soil Mechanics and Foundation Engineering, Fifth, Paris, 1961, Proceedings, vol.1, p.393-401.
The author carried out tests to discover the influence of several factors on three different compositions of a bentonite-cement grout. These factors include the mechanical effects of the shape and dimensions of the testing rotating vane, the velocity of this vane, and the duration of the mixing operation. The properties of the mixture studied are the efficiency of mixing, the decantation, the viscosity and the mechanized strength.

RESISTANCE OF FRESHLY INJECTED GROUT TO EROSION AND DILUTION BY FLOWING WATER P

Walley, D.M.

Vicksburg, Miss., U.S. Army Engineer Waterways Experiment Station, U.S. Army Engineers Information Exchange Bulletin, "Engineering and Scientific Research at WES," p.6-8, April 1977.
This article discusses the placement of various types of grout in flowing water. All grouts tested were of the suspension type, i.e.,

cement, fillers, and additives together with water. Diesel fuel was substituted for water in the design of two mixtures. Based on the relative resistance to the effects of flowing water, the fast-set types (i.e., those grout mixtures containing a quick-setting cement) were the most resistant of those tested.

FINITE ELEMENT ANALYSIS OF GROUT PROPAGATION

Wallner, Manfred and Wittke, W.

International Conference on Numerical Methods in Geomechanics, 2nd, Virginia Polytechnic Institute and State University, Blacksburg, June 1976. New York, American Society of Civil Engineers, vol.2, p.1119-1132, 1976.
This paper discusses the finite element technique in the study of a non-steady flow in a Bingham fluid as applied to grout propagation.

EIGENSCHAFTEN VON ZEMENTSUSPENSIONEN ZUM AUSPESSEN P

Walz, K.

Beton-und Stahlbetonbau, vol.49, no.9, September 1954, p.205-211.

METHODS OF CONTROLLING GROUT FOR PRESTRESSED, POST-TENSIONED STRUCTURES P

Weaver, R.E., and others

Sacramento, Calif., California State Division of Highways, Interim Research Report on Corrosion Control of Steel in Concrete.
A study was made to determine the effects of various admixtures, cement brands, and air entrapment/entrainment on the quality of neat cement grout. The relationship between these parameters and compressive strength was also investigated. A number of laboratory grout mixing experiments were performed. Results were tabulated and it was found that admixtures decreased compressive strengths and increased the bleeding of grout.

PRESENT STATE OF THE GROUTING INDUSTRY IN THE UNITED STATES C, P, M

Welsh, J.P.

Foundation for Dams, Engineering Foundation Conference, Pacific Grove, Calif., March 17-21, 1974, p.65-68. New York, N.Y., American Society of Civil Engineers.
An overview of the present state of the grouting industry in the United States.

WHICH GROUT? HOW TO CHOOSE AMONG SPECIALIZED GROUTS M

Concrete Construction, vol.19, no.10, p.501-504, October 1974.
Study of grouting techniques and selection among specialized grouts deals with ordinary grout, gas-forming grouts, non-catalyzed non-metallic grouts, and grouts for highly stressed applications.

AN INVESTIGATION OF THE INFLUENCE OF PRESSURE AND VISCOSITY ON THE FLOW OF 62-E-1 EPOXY GROUT BETWEEN PLANE SURFACES SEPARATED BY KNOWN DISTANCES C

Whitesides, G.W.

Louisville, Ky., George M. Whitesides Company, Inc., September 1963.
Conclusions of the test were: (a) both induced and capillary pressures are important in the spread of 62-E-1 Epoxy Grout in rock fissures, (b) the increase in pressure materially affects the rate of flow, and (c) in thin fissures, down to one mil, capillary pressure becomes more important.

INJEKTERADE DRAGSTAG I LERA (GROUTED TIE-BACKS IN CLAY) P, M

Widing, S., and Elfgren, L.

Byggmastaren, vol.50, no.5, p.22-28, 1971.
Series of tests performed to determine the suitability of some type of tie-backs for use in very soft clay. Experiments, including short-term and long-term loadings, residual strength and creep, were made after three groutings at various time intervals with cement-bentonite grout. In Swedish.

PRE-STRESSED GROUTED ROCK BOLTS, POSITIVE INSPECTION, WITH DE-AIR HOLE P

Williams Form Engineering Corporation

Grand Rapids, Mich., Rock Bolt Manual no.3-68, 1968.
Installation and grouting procedure for Williams pre-stressed groutable hollow rebar lock bolts; use of "Wil-Kwik-Set" and "Wil-Grout Additive."

TECHNIQUE FOR STUDY OF GRANULAR MATERIALS C

Windisch, S.J., and Soulie, M.

American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol.96, SM4, p.1113-1126, July 1970, Paper No.7389.

A technique is proposed for measuring characteristics to the grain-pore distribution of granular deposits without disturbing the original granular structure. The technique consists of successive phases of impregnation with two different types of grout, resulting in fixing the original grain configuration in a hard epoxy matrix.

GROUTING OF SAND AND GRAVEL C, P

Wing, S.P.

Colorado Society of Engineers, Engineers Bulletin, p.4-5, September 1935.
Minimum size openings and type of grout suitable.

HYDROFRACTURE MECHANISMS IN ROCK DURING PRESSURE GROUTING P

Wong, H.Y., and Farmer, I.W.

Rock Mechanics, vol.5, no.1, p.21-41, May 1973.
The paper examines the basic mechanisms controlling the initiation of fractures in rocks and layered soils during pressure grouting, and their subsequent propagation into the grouted mass. Previous analyses of fracture inititation have tended to concentrate on simplified models in which the ground is treated as an impervious elastic Mohr-Coulomb continuum. The present method allows for the porous or fissured nature of the ground by considering the effect of seepage forces induced by the pore pressure gradient. Analysis of hydrofracture propagation is based on stress analysis of a borehole in a continuum, the propagating fracture zone around the borehole being represented as a non-elastic material governed by the Mohr-Coulomb failure criterion. This is supplemented by an energy approach which equates the energy supplied to the ground from the injection pump, with the energy stored in the ground and the energy necessary to fracture it.

DEVELOPMENT AND APPLICATION OF A JAPANESE GROUTING SYSTEM

Yahiro, T., Yoshida, H., and Nishi, K.

International Water Power Dam Construction, vol.27, no.2, p.56-59, 83, Feb. 1975.
Discusses the principles and practical application of a newly-developed grouting system which effectively uses a high-speed water or air-and-water jet to break up the soil prior to grouting. The method involves constructing an underground cutoff wall by injecting grout into a slit made in the soil by a high-speed water-and-air jet.

ON THE CHARACTERISTICS OF HIGH SPEED WATER JET IN THE LIQUID AND ITS UTILITZATION ON INDUCTION GROUTING METHOD M

Yahiro, T., and Yoshida, H.

International Symposium Jet Cutting Technology, 2nd, University of Cambridge, UK, April 1974, Proceedings, Paper G4, p.41-63. Cranfield, England, BHRA (British Hydromechanics Research Association) Fluid Engineering, 1974.

Induction grouting method, making a slit by high speed water jet in which grouting materials are sent, is very useful in the point of energy efficiency and grouting effect. The authors clarified the experimental properties of high speed water jet, changing liquid objects, e.g., water, bentonite slurry and mud slurry. The authors also devised the method of jetting water with air to improve the excavation capacity by high speed water jet.

INJEKTIONEN IM UNTERGRUND (UNDERGROUND INJECTIONS) C, P, M

Zmarzly, H.R.

Monierbauer, no.1, p.4-7, 1975.

Gives a survey of the various types of injections and of the methods of their execution for dam construction, gallery construction, and foundation engineering. The most widely used injections are: (a) cement injections with addition of bentonite, clay, fine sand, or filter ash, (b) clay gel, (c) chemical solutions on the basis of sodium silicate, and (d) synthetic resins.

RUCKWARTIGE VERANKERUNGEN VON BAUGRUBENWANDEN: TEIL II (TIE-BACK ANCHORAGE OF SHEETINGS OF EXCAVATIONS: PART II)

Zweck, H.

Veroffentlichungen Haus der Technik, Essen, no.241, p.32-49, 197[illegible].

A discussion of pressure grouted anchors is included. When using this kind of anchor, a grout body is made by pressuring cement grouts around the back part of a tension member made of steel, previously inserted in the soil.

INDEX

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

United States. Waterways Experiment Station, Vicksburg, Miss.
Bibliography on grouting. Vicksburg, Miss. : Technical Information Center and Concrete Laboratory, U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
325 p. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; C-78-8)
Prepared for U. S. Army Materiel Development & Readiness Command, DRCDE-E, Alexandria, Virginia, under Program Element 65 803A, Project 1T865803M728, Task 00, Work Unit 004.
CTIAC Report No. 13.

1. Grouting. 2. Chemical grouting. 3. Cement grouting. 4. Bibliography. I. United States. Army Materiel Development and Readiness Command. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; C-78-8.
TA7.W34m no.C-78-8